NATIONAL URANIUM TAILINGS PROGRAM

Energy, Mines and Resources Canada

Énergie, Mines et Ressources Canada

Canada

LITERATURE REVIEW OF
RADIONUCLIDE MOVEMENT THROUGH
THE BIOSPHERE

167pp

DSS 15SQ.23317-6-1724
Serial No. 23317-61724-01-SQ

LITERATURE REVIEW OF RADIONUCLIDE MOVEMENT THROUGH THE BIOSPHERE

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October 1986

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DSS 8279-0/3989

MICROMEDIA

EXECUTIVE SUMMARY

The objective of this study has been to carry out a review of the literature on radionuclide concentrations and mechanisms of transfer through the environment from vegetation and animals to man. A large number and variety of documents dealing with radionuclide movement in the biosphere have been assessed, with a relatively small subset of these being identified as being relevant to locations in Canada where uranium tailings occur.

It is concluded that site-specific input data will always be preferred for site-specific model applications. A limited amount of applicable data for this purpose has been identified, but further field investigations are definitely required. General guidelines for futher data collection are identified.

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PART 1

INTRODUCTION

PART 1 - INTRODUCTION

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1.1 INTRODUCTION

One objective of the National Uranium Tailings Program (NUTP) has been the development of a predictive computer simulation model for the movement of radionuclides from uranium tailings sites through the natural environment. As part of the tasks required to meet this objective, background information on discrete levels of relevant radionuclides in environmental compartments and on mechanisms by which transfer occurs between compartments is required. These types of information will be useful in fully assessing the model outputs as well as in defining input values for site-specific simulations.

1.2 SCOPE AND REPORT ORGANIZATION

The overall object of this study has been to carry out a review of the literature on radionuclide concentrations and mechanisms of transfer through the environment from vegetation and animals to man. The scope of the work has included:

- search and definition of literature;
- assessment of relevant literature for applicability; and
- identification of site-specific and general data needs.

While this information was required as a basis for the NUTP modelling process, the review was not oriented toward the requirements of any particular computer model but rather attempted to identify suitable data which could be used in any modelling exercise.

The report is essentially organized into parts according to the above three categories. The following sections of Part 1 address the conceptual framework for radionuclide transfer, and also the regional context in which uranium tailings are found in Canada. Part 2 provides a summary and review of the relevant literature, organized in tabular form. Part 3 discusses the deficiencies in the data and suggests an approach to further data gathering.

1.3 REGIONAL CONTEXT

Currently, production of uranium is limited to two areas of Canada: northern Saskatchewan, and the Elliott Lake area of northern Ontario. A number of other mines are no longer active, including those in the Northwest Territories (Port Radium, Rayrock and Baker Lake), the Uranium City area in northern Saskatchewan, and locations in Ontario including Bancroft. At present, exploration for new commercial deposits is limited to northern Saskatchewan and Labrador.

In general, most of these uranium mining areas are located on the Precambrian Shield, in areas classified as Northern Boreal Forest (Elliott Lake is an area transitional to this forest type).

Most inactive, active and prospective sites are also located in areas of low population density. This is particularly true of those sites now abandoned in the Northwest Territories, although less so in the Elliott Lake area. Agriculture is not a major land use in any of these cases. Pathways to man through conventional agricultural crops are hence much less likely to be important than those related to the harvest and consumption of non-cultivated crops (i.e. wild rice, blueberries) or non-domesticated wildlife (fish, deer, moose, caribou).

1.4 CONCEPTUAL FRAMEWORK

When radionuclides from a uranium mining/milling facility are discharged into the environment, they are diluted and dispersed but may eventually accumulate in specific compartments or spatial locations. These processes are governed by a highly complex array of interacting physical, chemical and biological factors, many of which are also time- or site-specific. This movement of materials (including radionuclides) within ecosystems is often conceptually described in terms of transport processes which move material from one compartment to another. Figure 1-1 is one example of this type of conceptual approach to analysis. This simplification provides a framework for organizing knowledge about ecosystem structure and function.

An alternate generalized environmental transfer pathway diagram has previously been developed (Beak Consultants Ltd. 1985) for the AECB, and is adapted here in slightly modified form as a basis for structuring this report (Figure 1-2). Those compartments and pathways marked in red were given most emphasis in the review, while those identified in green received lower priority in terms of database searches and evaluation. While a distinction was attempted between those publications dealing with concentrations or activities of the most relevant radionuclides in the defined compartments, and those dealing with the transfer pathways between compartments in practice there was considerable overlap between these categories. The designations for compartment numbers and pathway numbers have been adopted in this report.

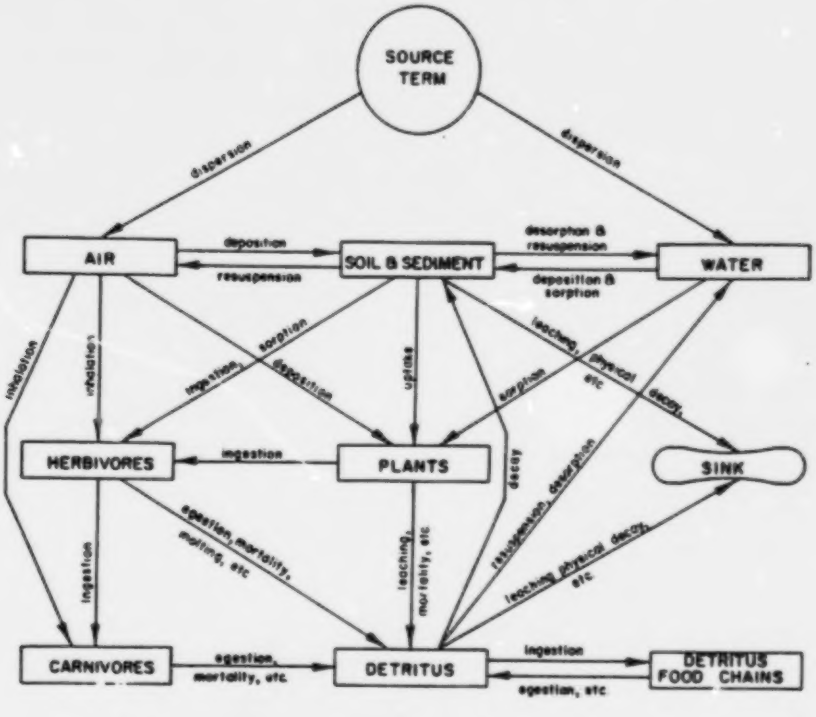
SOURCE TERM
dispersion
dispersion
AIR
deposition
resuspension
SOIL & SEDIMENT
desorption & resuspension
deposition & sorption
WATER
inhalation
inhalation
ingestion, sorption
deposition
uptake
leaching, physical decay, etc
sorption
decay
resuspension, desorption
HERBIVORES
ingestion
PLANTS
SINK
ingestion
egestion, mortality, molting, etc
leaching, mortality, etc
leaching physical decay, etc
CARNIVORES
egestion, mortality, etc
DETRITUS
ingestion
egestion, etc
DETRITUS FOOD CHAINS

FIGURE 1-1

Major Ecosystem Components and Processes (from Whicker and Schultz 1982)

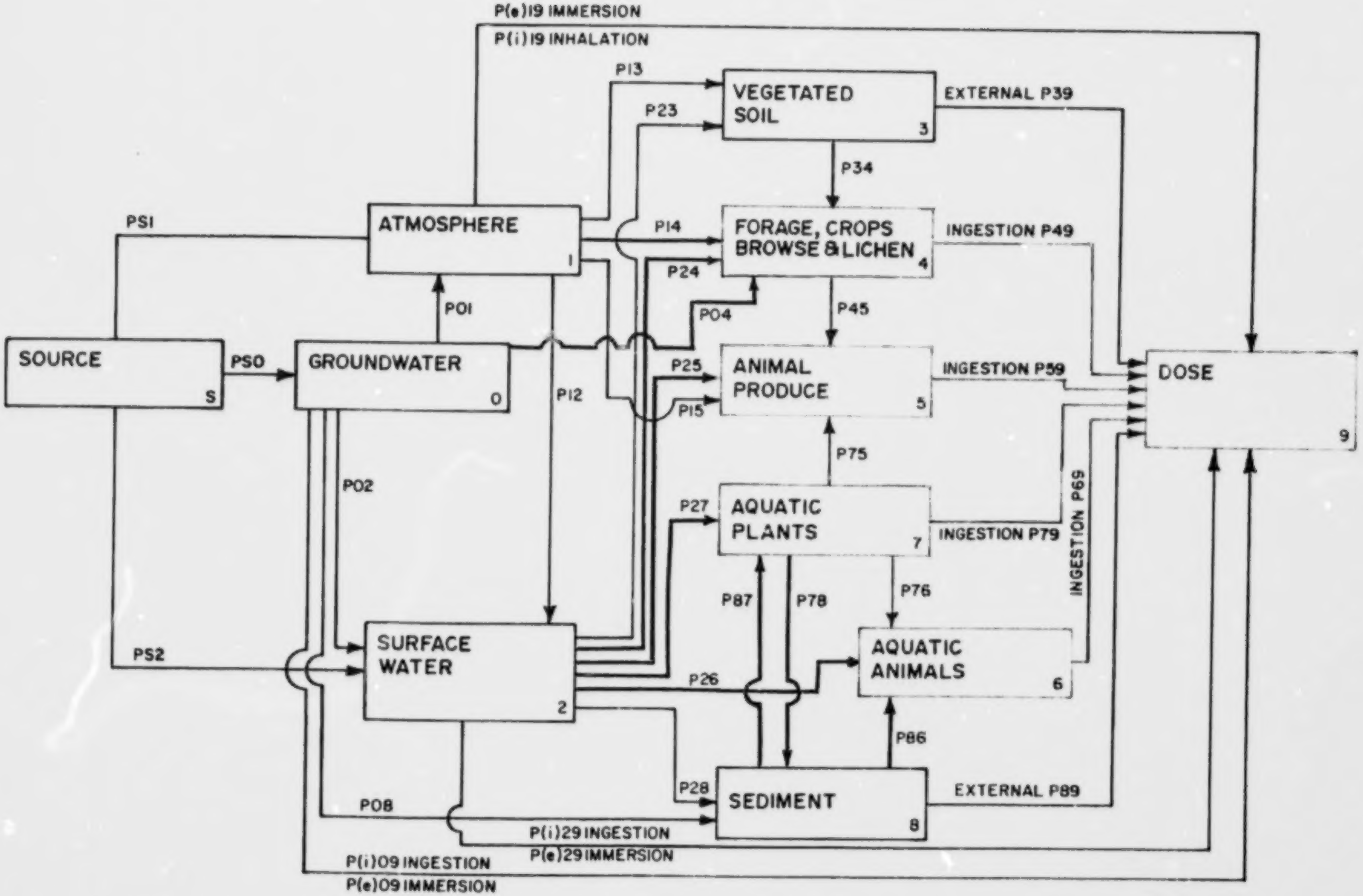
P(e)19 IMMERSION
P(i)19 INHALATION
P13
P23
VEGETATED SOIL 3
EXTERNAL P39
P34
PS1
ATMOSPHERE 1
P14
P24
FORAGE, CROPS BROWSE & LICHEN 4
INGESTION P49
P01
P04
P45
SOURCE S
PS0
GROUNDWATER 0
P12
P25
P15
ANIMAL PRODUCE 5
INGESTION P59
DOSE 9
P02
P75
P27
AQUATIC PLANTS 7
INGESTION P79
INGESTION P69
P87
P78
P76
PS2
SURFACE WATER 2
P26
AQUATIC ANIMALS 6
P86
P28
SEDIMENT 8
EXTERNAL P89
P08
P(i)29 INGESTION
P(e)29 IMMERSION
P(i)09 INGESTION
P(e)09 IMMERSION

FIGURE 1-2 Generalized Environmental Transfer Pathway Diagram

PART 2

DATABASE DESCRIPTION AND EVALUATION

PART 2 - DATABASE DESCRIPTION AND EVALUATION

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2.1 LITERATURE REVIEW

The literature review was initiated with a computerized search of the following data bases:

- Agricola;
- Agris;
- Enviroline; and
- SciSearch.

Key words used to search each of the above data bases were:

- Radionuclide with Migration;
- Radionuclide with Transport;
- Radionuclide with Pathways; and
- Radionuclide with Transfer.

Based on the results of the first computer survey, a limited second survey was made of the International Nuclear Information System (INIS) using the above key words. This limited survey demonstrated such a large amount of redundance with the first survey that a third survey of the INIS was initiated with the key words:

- Radionuclide Migration Model(s);
- Radionuclide Transportation Model(s); and
- Radionuclide Pathway(s) Model(s).

Much of the information provided in the third survey was also redundant. The literature review then shifted to a review of material cited in the documents received as a result of the computerized survey or already on file in Monenco's library or the personal libraries of Monenco staff.

The summary tables contained in this section present publications related to radionuclide concentrations in various environmental compartments (Table 2-1) and the various pathways by which radionuclides are transferred among compartments (Table 2-2). The thrust of the literature review in both cases has been toward those radionuclides which are associated with uranium mining and milling (i.e. Ra-226, Th-230, Pb-210, Po-210 and uranium). However, in the case of Table 2-2 (pathways) the scope of the literature has been purposely widened to include generic pathway studies in which the conceptual framework of radionuclide transfer is addressed without reference to a specific radionuclide. Further evaluation of this literature in the context of the computer simulation modelling process is included in Part 3 of this report.

2.1.1 ENVIRONMENTAL COMPARTMENTS

Publications related to radionuclide concentrations in various environmental compartments are presented in Table 2-1. The compartments of concern in this report are:

- Forage, Crops, Browse and Lichen	(4);
- Animal Produce	(5);
- Aquatic Plants	(7);
- Aquatic Animals	(6).

The compartment given the most attention in the scientific literature among those selected for study appears to be the "Forage, crops, browse, lichen" compartment. This is an especially important compartment because radionuclides may accumulate in it by way of atmospheric deposition, contact with contaminated solids (i.e. soil and/or tailings) or contaminated surface water or groundwater. Likewise this compartment forms an important component in the diet of man, supplying his energy needs both directly and indirectly through herbivorous animal produce. A great variety of studies have explored this compartment for reasons such as:

- basic information on the human intake of naturally occurring radionuclides in areas affected by uranium mining;
- gathering baseline data from areas of high or normal background radioactivity;
- determination of the efficiency of transfer of specific radionuclides from the soil to the plant;
- determination of the efficiency of transfer of specific radionuclies from the plant to a herbivorous animal; and
- determination of the fate of a particular isotope in a given environmental setting.

Fewer studies have been conducted on the uranium and thorium series radionuclides in the animal produce, aquatic animals and aquatic plant compartments. The animal produce and aquatic animals (chiefly fish) compartments are integral parts of the human diet and merit attention from this viewpoint. However, the aquatic plants used in almost all of the studies reviewed have no direct relation to human diet. Reasons for this emphasis are speculative, but may be related to the fact that aquatic plants in general (and phytoplankton in particular) are known to play an important part in the removal of radionuclides from surface waters. This ability is the result of the surface ion exchange capacity of the cell walls and absorption of the radionuclide into the cell.

There is among all the studies of the uranium and thorium series radionuclides in the compartments of concern, a general lack of replication either among samples or among analyses. As well, only the most recent publications have any discussion pertaining to analytical quality control. Much of the data presented must be accepted on the basis of faith in the author and pre-publication article reviewers for its accuracy, reproducibility and representivity.

Compartmental studies concerning uranium mining associated radionuclides can be divided into two categories:

- those dealing with the conditions encountered at uranium mine sites; and
- those dealing with the same or similar isotopes in other situations and environments, including laboratory studies.

Unfortunately, not all of the studies dealing with uranium and thorium series radionuclides in the environment influenced by this type of operation are representative of the Canadian uranium mining and milling situation. For example, all Canadian uranium mill tailings are at or near saturation with water (Dory 1981). Many of the uranium mill tailings in the western U.S. are very dry and require irrigation for significant plant growth to become established and maintained. Other differences such as soil and tailings chemistry, local climate and resident plant and animal species among uranium mines in North America result in compartmental studies which are only representative of the general area in which they are conducted. Extrapolation of the data to other uranium mine sites in significantly different climatic zones becomes tenuous at best.

Field and laboratory studies conducted with the same or similar radionuclides associated with uranium mining in areas remote from this type of operation generally have little relevance to conditions at Canadian uranium mine sites. These studies are conducted for the variety of reasons previously itemized. Only a select few of these studies have applied the analytical expertise and experimental designs which would allow use of the data in modelling the dispersion of radionuclides from uranium mining and milling operations. This use may be limited to one compartment under specific conditions related to radionuclide levels in associated compartments.

TABLE 2-1

Literature Summary - Environmental Compartments

Environ. Compartment	Citation	Data Collection Methods	Analytical Techniques	Replication	Representivity
Forage, Crops Browse & Lichen(4)	Dave et al. 1985	Blueberries, handpicked wine from above.	Ra-226; wet ashed; alpha spectrometry; NBS calibration standards used.	No; 1 kg sample from each site.	Unknown.
Vegetated Soil (3) Forage, Crops Browse & Lichen(4) Animal Produce (5)	Rayno 1982	Compilation of Literature values for U-238, U-234, Th-230, Ra-226, Pb-210, Po-210.	None.	None.	Food chain movement of tailings radionuclides via the forage vegetation to cattle to meat/milk to man pathway assuming: 1) radioactive equilibrium exists between Th-230, Ra-226, Pb-210 and Po-210; and 2) 5 pCi/g as an estimate of radionuclide activity taken up by forage.
Forage, Crops (4) Animal Produce (5)	Watson et al. 1983	Literature review.	None.	None.	Very general; not specific as to location, not sufficiently representative of uranium tailing for use.
Aquatic Animals(6)	Swanson 1985	Dipnet/scraping (insects), beach seine/fish trap, gill net.	Insects: nitric/perchloric digestion. Fish: frozen prior to ashing at 500°C or component parts. (i.e. skin, muscle, liver, etc.) frozen separately prior to ashing at 500°C. Analytical methods: CANMET 1979. Pb-210: BiOCl ppt. Ra-226: Ba(Ra)SO4 ppt. with alpha spectrometry.	None.	Study carried out in Beaverlodge Lake area of northern Saskatchewan. Data would appear to be representative of Canadian uranium tailings impacts on aquatic environments.

TABLE 2-1 (Cont'd)

Environ. Compartment	Citation	Data Collection Methods	Analytical Techniques	Replication	Representivity
			U: Fluorometry and neutron activation.		
Aquatic Plants (7) Aquatic Animals(6) Animal Produce (5)	Lush et al. 1982	Literature values only for U-238, U-234, Th-230, Ra-226, Pb-210, Po-210, Th-232, Ra-228, Th-228.	None.	None.	Single set of transfer coefficients given are too general to predict population dose commitments for various groups of people from the Serpent River area to Great Lakes area and then finally to the Atlantic Region. The assumption that given coefficients apply along this pathway is doubtful.
Forage, Crops (4) Animal Produce (5)	McDowell-Boyer et al. 1979	Literature Review for Pb-210.	None.	None.	This data is not representative of conditions existing at Canadian uranium mine sites.
Forage, Crops (4) Animal Produce (5) Aquatic Animals(6)	Klement 1965	Literature Review, particularly U-238, Th-230, Ra-226, Pb-210, Po-210.	None.	None.	Values not representative of material derived from or affected by uranium mining and milling.
Forage, Crops (4)	Rumble & Bjugstad 1986	1.0 kg dry wt. of clippings from 0.125 m^2 circular plots along transect.	Not stated. Analysis by U.S. Testing, Inc. Richland, WA, U.S.A.	5 circular plots along transect	Specific to uranium mill tailings site in South Dakota U.S.A. Mill tailings were reprocessed mill sands covered with topsoil and seeded to mixture of wheatgrass, sweetclover and rye. Soil covering tailings ranged in depth from 10 to 30 cm.

TABLE 2-1 (Cont'd)

Environ. Compartment	Citation	Data Collection Methods	Analytical Techniques	Replication	Representivity
Forage, Crops (4) Animal Produce (5) Aquatic Animals(6)	Russel & Smith 1966	Literature Review for Ra-226, Th-232, and U-238.	None.	None.	General discussion of Ra-226, Th-232 and U-230 in soils and plants from selected world-wide sources. Values from areas of exceptionally high background are excluded. Presented values are not representative of conditions existing at Canadian uranium mines.
Forage, Crops (4) Animal Produce (5) Aquatic Animals(6) Aquatic Plants (7)	Hallden & Fisenne 1961	Foods from New York City, Chicago and San Francisco composited by city. Food divided into 19 categories.	Composite samples for each city ashed at 600°C for minimum of 5 g of ash. Details of chemical separations not given although sufficient quality control during counting was used. Samples analyzed by Health and Safety Laboratory, U.S. Atomic Energy Comm.	Not stated, but samples were re-run if barium carrier showed low recovery.	Compartment values are specified to three U.S. cities and are not representative of values which would be anticipated at uranium mine sites.
Aquatic Plants (7)	Kalin and Sharma 1982	Plant excavated with spade and parts segregated. Roots and rhizomes transported with substrate, subsequently washed with distilled water. Washings and sediments mixed, allowed to settle and supernatant filtered (0.45 u).	Dried and blended parts wet-oxidized with nitric acid for 120 hr. Completeness of oxidation by NBS material comparisons. Plant digests passed through cation-exchange column. Eluant evaporated and contacted with DADDC in p-xylene; assayed with gas-flow proportional counter.	Not stated.	Compartment values should be representative of those found at uranium tailings sites.

TABLE 2-1 (Cont'd)

Environ. Compartment	Citation	Data Collection Methods	Analytical Techniques	Replication	Representivity
Forage, Crops (4)	Marple and Potter 1982	Not stated. Native and naturalized plants growing on bare tailings and covered tailings were collected in the Grants Mineral Belt of New Mexico.	Gamma spectroscopy using Ge (li) detectors to measure Bi-214 for Ra-226 activity in oven-dried or ashed samples. Samples were sealed to establish Ra-226/Bi-214 secular equilibrium.	Not stated.	Compartment values represent two perennial grasses, two annual forbs and a perennial shrub growing in the arid environment of the U.S. Southwest. These values cannot be considered representative of Canadian uranium mine sites.
Aquatic Animals(6)	Stegnar and Kobal 1982	Fish collected by electroshocking.	Ra-226 by alpha scintillation technique measuring the emanation of Rn-222 of a completely digested sample (digestion method not stated). Uranium by neutron activation analysis for low concentrations. High values were determined by the fluorimetric method.	Not stated.	The compartment values for Ra-226 and Uranium depend on the location at which the fish were sampled. Only those values for the radionuclides in fish from downstream of the uranium mine area would be representative of conditions downstream of Canadian uranium mine site.
Aquatic Animals(6) Forage, Crops (4)	Kovalsky et al. 1967	Not stated.	Not stated.	Not stated.	Although concentrations of uranium are given for fish bones, roe, gonads, kidneys, muscles, blood and brain as well as terrestrial plants and soil the complete lack of information concerning these values make it impossible to use in relation to Canadian uranium mine sites.

TABLE 2-1 (Cont'd)

Environ. Compartment	Citation	Data Collection Methods	Analytical Techniques	Replication	Representivity
Forage, Crops (4) Animal Produce (5)	Verkhovskaja et al. 1967	Not stated.	Not stated.	Not stated.	This article is a summary of work carried out by the radiobiological laboratory of the Komi branch of the U.S.S.R. Academy of Sciences in various zones of the northern tiaga "where increased radioelement content is conditioned either by surface bedding of respective rocks or by the outcrop of deep-set stratified highly radioactive waters". As such the data presented in this article are not representative of conditions associated with Canadian uranium mining.
Animal Produce (5) Forage, Crops (4)	Kauranen & Miettinen 1967	Duplicate samples of about 10 g dry weight of plant and reindeer from Lapland; plant and elk samples from southern Finland for Po-210 and Pb-210 analysis.	Wet oxidation (nitric/perchloric) plated out on silver disks from neutralized sample solution. Alpha activity counted by ZnS(Ag) scintillation counter. For very low-level activity, known quantity of Po-209 and tellurium carrier was added at beginning of analysis. Polonium was coprecipitated on Te, the Te precipitate was redissolved and removed and polonium plated out on a small area.	Duplicates.	Origin of Pb-210 (and Po-210) in this study was "natural fallout". This along with the use of earlier analytical methods make this data difficult to interpret for application to Canadian uranium mining sites.

TABLE 2-1 (Cont'd)

Environ. Compartment	Citation	Data Collection Methods	Analytical Techniques	Replication	Representivity
Browse & Lichen(4)	Blanchard 1967	Not stated. All lichen samples were washed in distilled water before analysis for Po-210 and Pb-210.	Dissolution in hot, conc. HNO_3 and fumed in $HClO_4$ until clear. Neutralized with 18N NaOH, diluted to 100 mL with distilled water and made 0.5N in HCl. 200 mg of ascorbic acid added for solution heated to 85°C beneath a watch glass. Silver disc (coated on one side with polyethylene) suspended in solution for 4 hr. After deposition, rinsing and drying, alpha activity measured with ZnS(Ag) scintillation counter.	Not stated.	This paper gives Po-210 and Pb-210 activities for various lichens and mosses and caribou bone and meat samples. This data is useful only for backup information.
Aquatic Plants (7) Aquatic Animals(6)	Beak Consultants Limited 1986	Vegetation: Each sample was collected as a composite of several plants. Only above ground portions were included. All vegetation was collected from tailings sites or waste rock pile. Fish: gill net. Fish were dissected and organs combined to maximum of 500 g. Tissue samples on dry ice until shipment.	Chiu and Dean (1984). Ra-226 and thorium were determined by high resolution alpha spectrometry following pyrosulphate fusion. Lead-210 was determined indirectly by measurement of Bi-210 using a beta-counter, following pyrosulphate fusion.	Vegetation: Samples of each community from 10 randomly placed 0.25 m^2 quadrats. Samples for radionuclide analysis were composites of these random samples. Animals: not stated.	This study was conducted at a Canadian uranium mine and tailings site (Gunnar area, N. Saskatchewan). The samplings and analytical techniques were state-of-the-art. The values obtained for the various compartments (aquatic plants, aquatic animals) are representative of conditions at Canadian uranium mines.

TABLE 2-1 (Cont'd)

Environ. Compartment	Citation	Data Collection Methods	Analytical Techniques	Replication	Representivity
Aquatic Animals(6) Aquatic Plants (7) Animal Produce (5) Forage, Crops (4)	Mahon 1982	Vegetation hand collected, mix plankton samples collection techniques not stated. Benthos collected by Ekman grap samples. No information on terrestrial techniques or methods.	Vegetation frozen at -20°C after collection, ground in Wiley mill to pass through 10 mesh. Portion of this material ashed, at 550°C, digested in fuming perchloric acid for U, Pb-210 and Ra-226 analysis. Second portion wet digested in fuming perchloric acid for Po-210. Whole animal samples washed in distilled water, air dried at 110°C for 48 hours prior to analysis. Animal material was homogenized, ashed at 550°C and digested as for the vegetation samples. Uranium measured by spectrofluorimetry. Ra-226 separated by co-precipitation with $BaSO_4$ and stored one week for ingrowth of Rn-222 and daughters. Precipitate analyzed by alpha and beta analysis. Pb-210 measured by beta activity of Bi-210 after 30 days equilibrium. Po-210 measured after electrodeposition on silver discs.	Not stated for sampling or analysis.	This study was conducted in the Okanagan Highlands of Central British Columbia. This data is representative of the Canadian environment, and while data from specific uranium tailings sites will always be preferable for modelling applications, this data does have relevance. For example, the accumulation of radionuclides by clams as examined in this study may be used for modelling of tailings impacts should more site specific information be non-existent.

TABLE 2-1 (Cont'd)

Environ. Compartment	Citation	Data Collection Methods	Analytical Techniques	Replication	Representivity
Aquatic Plants (7)	Dusauskene-Duz and Polikarpov 1978	Not stated.	Samples ashed (no temp. given) and treated with nitric acid with $Pb(NO_3)_2$ carrier and evaporated until dry. Residue boiled in HCl, filtered and passed through a column of anion-exchange resin. Pb-210 determined by precipitation of hydroxide at pH 9 to 10. No other information given.	Not stated.	This study was conducted on natural Pb-210 concentrations in Lithuanian lakes and cannot be considered representative of conditions at Canadian uranium mine sites.
Aquatic Plants (7)	Justyn and Stanek 1974	Not stated.	Samples dried at 105°C to constant weight, ashed at 550°C ground and dissolved and Ra-226 measured emanometrically. Uranium: ash fused with soda and melt dissolved and fumed off with HCl and HNO_3. Uranium hydroxide precipitated with ammonia, then dissolved in HCl and filtered. Uranium determined by visual luminescence method.	Not stated.	Although the radionuclide concentrations in the aquatic plants of this study were taken from aquatic environments impacted by uranium tailings, the lack of information regarding sample collection, replication and analytical techniques suggest that application of this data for modelling uranium mine tailings impact would require supporting measurements.

TABLE 2-1 (Cont'd)

Environ. Compartment	Citation	Data Collection Methods	Analytical Techniques	Replication	Representivity
Forage, Crops (4)	Dean 1966	Pine needles and leaves of rhododendron or laurel collected in autumn at 41 points of a 50 mile grid drawn across Great Britain. Samples were taken away from roads and other obvious sources of surface contamination unless sources were typical of general locality (i.e. heavy industrial fallout or near abandoned uranium mine).	Neutron activation analysis. Samples ashed in porcelain dishes at 700°C, ash ground in agate mortar.	Duplicate analyses were performed. No information on sampling replication.	The data generated by this study is generally of a background nature and not representative of conditions around Canadian uranium mining sites.
Aquatic Plants (7)	Havlik 1970	Plankton net (60 u) and concentrated by filtration (0.8 u), dried for 12 hr @ 90°C and weighed.	Dry residue dissolved in HNO_3 and H_2O_2, evaporated to dryness and redissolved in HCl. Samples divided into 2-25 mL portions, citrate buffer, EDTA solution and egg albumin added. Known amount of Ra-226 added to one half of each sample. All solutions shaken with glass plates coated with a layer of hardened gelatine with dispersed $BaSO_4$. Plates removed, washed, dried at room temperature, counted after 5 and 30 days of storage. Counting with alpha scintillation with ZnS(Ag) screen.	None.	This study reported background concentrations of Ra-226 in water and plankton from Chalk River area and are not representative of conditions of uranium mine sites.

TABLE 2-1 (Cont'd)

Environ. Compartment	Citation	Data Collection Methods	Analytical Techniques	Replication	Representivity
Aquatic Animals(6)	Pentreath et al. 1979	Not stated.	Fish organs dissected out and ashed at 550°C, analysis by spark source mass spectrometry. For Po-210, wet samples were wet oxidized in nitric and perchloric acids, and neutralized with sodium hydroxide. Solutions were made 0.5 molar with respect to hydrochloric acid and Po-218 removed by spontaneous deposition onto silver discs at 90°C in presence of ascorbic acid. Discs then alpha counted.	Not stated.	This study represents an assessment of the alpha-emitting radionuclides accumulated in fish of the Irish Sea from the nuclear fuel reprocessing plant at Windscale, England. It is not representative of conditions occurring at Canadian Uranium mines.
Forage, Crops (4)	Hill 1960	Grass collected from 20 well separated points in the southern part of Great Britain.	Not stated.	Not stated.	Pb-210 and Po-210 in grass as derived from decay of atmospheric radon deposited on grass by rainfall. These background concentrations of Pb-210 and Po-210 are not representative of conditions at Canadian Uranium mine sites.

TABLE 2-1 (Cont'd)

Environ. Compartment	Citation	Data Collection Methods	Analytical Techniques	Replication	Representivity
Aquatic Animals(6)	Poston 1982	Laboratory study. Rainbow trout exposed to thorium and uranium solutions in static enclosures. Samples of fish were collected at 3, 9 and 27 days during uptake and 5, 25 and 125 days during depuration in Thorium exposures. Samples of fish were collected at 6 and 35 days during Uranium uptake. Collections during depuration not stated.	Whole body uptake of Th, including gastrointestinal tract, determined by counting Pb-212 daughters in a NaI well crystal coupled to a single channel analyzer. Samples counted 60 days after processing. Processing methods not stated. Uranium analytical techniques not stated.	10 fish per sample.	Study related to release of Th and U from uranium (and potentially thorium) reactor fuels or fuel processing facilities. These data do not represent conditions related to Canadian Uranium mining.
Aquatic Animals(6) Aquatic Plants (7)	Hesslein and Slavicek 1984	Fish collected by gill net, trap net, hook and line; crayfish collected in modified minnow traps. All samples frozen within hours of capture and transported to Lab. Macrophytes collected by hand in shallow water.	Samples were digested by slow addition of nitric acid, then heated until acid fuming ceased. Procedure repeated as necessary until only small residue remained. The residue was fired at 450°C for 6-10 hr. to produce white ash. Firing not necessary for plant material Ra-226 measured by radon emanation method in which daughters Po-218 and Pb-214 are measured by alpha-scintillation counting.	Not stated.	Although Ra-226 additions were made to these northwestern Ontario lakes for reasons other than determining its distribution and biological uptake, the manner in which the research was conducted, the experience of the investigators and the analytical techniques used, permit the resulting of information to be applied at any location (including uranium mining sites) where Ra-226 is introduced into the aquatic environment.

TABLE 2-1 (Cont'd)

Environ. Compartment	Citation	Data Collection Methods	Analytical Techniques	Replication	Representivity
Aquatic Plants (7) Aquatic Animals(6)	Martin et al. 1967	Not stated.	Samples were ashed (temp. unknown) and the Ra-226 determined by the radon emanation method using a scintillation flask.	Not stated.	The data presented in this paper are derived from uranium mining and milling areas in the U.S. Unfortunately, the data quality is deemed insufficiently well defined for use in modelling.
Forage, Crops (4)	Ibrahim et al. 1982	Vegetation samples collected from (1) reclaimed tailings sites, (2) directly on exposed, weathered tailings in the lee of tailings pond dams and near tailings ponds at distances of 0.05 to 9 m from the edge. Current annual aboveground growth was clipped by hand to provide 15-50 g of dry matter. Plant groups sampled were mixed grasses, sagebrush and forbs.	Vegetation was ultrasonically washed in mild detergent and distilled water (twice). Samples were oven-dried at 70°C for 12 hours. For samples containing comparatively high levels of Ra-226, a gamma spectrometry method was used. For low-level samples, radon emanation was used.	Not stated.	The data obtained from this study are representative of uranium tailings areas in the semi-arid U.S. Southwest. Although the information (e.g. relative accumulation from soil) may be used in a general sense, extrapolation of specific data to Canadian uranium mine sites appears doubtful.
Forage, Crops (4) Animal Produce (5)	Holtzman 1966	Not stated	Samples were wet-ashed in concentrated nitric acid/perchloric acid. Dissolved sample was fumed with conc. HCl 4 times and then diluted and pH adjusted to 0.3. Po-210 plated on silver disk and counted in an internal flow pro-	Not stated.	Although the information contained in this work concerning radionuclides in lichens, fodder, caribou muscle (from Alaska) and reindeer muscle (from Finland) would appear useful in modelling pathways at Canadian uranium

TABLE 2-1 (Cont'd)

Environ. Compartment	Citation	Data Collection Methods	Analytical Techniques	Replication	Representivity
			portional alpha counter. Subsequent replating of sample after 3 mo. allowed estimate of Pb-210 and Po-210. Ra-226 was determined by the emanation technique.		sites, the information is for background levels and thus may not represent conditions at Canadian uranium mine sites.
Aquatic Plants (7)	Marchyulenene et al. 1978	Not stated.	Not stated.	Not stated.	The accumulation of Pb-210 in freshwater plants (macroalgae and vascular plants) in 5 Lithuanian lakes was described in this paper. This information cannot be used for any purpose related to Canadian uranium mine sites.
Aquatic Plants (7)	Mahon and Matthews 1983	Pond-lily (*Nuphar lutea*) floating leaves and petioles collected by hand then frozen at 20°C.	Samples ground in a Wiley mill to pass through a 10 mesh screen, ashed at 550°C and digested in fuming perchloric acid for Cl, Pb-210 and Ra-226. Second portion of the material was wet digested in fuming perchloric acid for Po-210 analysis. Uranium was measured by fluorescence. Ra-226 was separated by coprecipitation with $BaSO_4$, stored for one week and analyzed on an alpha-beta analyzer. Pb-210 was measured indirectly by beta activity of the daughter Bi-210 after 30 days. Po-210 was measured by alpha counting after electrodeposition on silver discs.	Not stated.	The plants used for this study were taken from an area of British Columbia of high natural radioactivity. The values obtained in this study can be used as a conservative estimate (if water concentrations are comparable) of Ra-226, Pb-210 and Po-210 content of this species alone at uranium mine sites if specific site data is not available.

TABLE 2-1 (Cont'd)

Environ. Compartment	Citation	Data Collection Methods	Analytical Techniques	Replication	Representivity
Aquatic Animals(6)	Justyn and Lusk 1976	Fish collected by electroshocking. No additional information given.	Samples ashed (550°C). Ra-226 determined emanometrically; Uranium by reduction with zinc and ascorbic acid with resulting blue-green complex measured photometrically at 665 nm.	Not stated.	This study identified Ra-226 and Uranium in fish in an area of Czechoslovakia influenced by uranium mining. Because of perceived collection and analytical shortcomings, it is difficult to support use of this data in relation to Canadian uranium mining sites.
Aquatic Plants (7)	Havlik 1967	Areas sampled: 5 rivers, 6 brooks and 2 ponds, 3 to 5 times in one year. Some sites were influenced by radioactive effluents (i.e. uranium mines).	Samples were ashed (temp. not stated) and apparently dissolved with the Ra-226 content measured by means of Vleek's sorbemulse method using gelatine plates with a specific carrier.	Not stated.	Although the Ra-226 contents of aquatic plants reported originate from environments impacted by uranium mining, the remoteness of the location from Canada and the analytical techniques used make the compartmental data in this publication unsuited for use in radionuclide pathway modelling of Canadian uranium mining sites.
Aquatic Plants (7) Aquatic Animals(6)	Anderson et al. 1961	Organisms collected with screen approx. 3.3 x 3.3 m with wood supports on either side. Approx. 1 m^2 in front of screen and rocks removed and substrate disturbed. Fast flowing river water washed organisms onto screen for collection and preservation.	Not stated.	Not stated.	The data reported in this study is specific to the site location (Animas River, Colorado and New Mexico) and lacks any information concerning the analytical techniques employed. Thus, this data is not suitable for use in any modelling of radionuclides at Canadian Uranium mining sites.

TABLE 2-1 (Cont'd)

Environ. Compartment	Citation	Data Collection Methods	Analytical Techniques	Replication	Representivity
Forage, Crops (4)	Bunzl and Kracke 1984	Grass samples collected in Spring (May). Young green leaves and dead plant material from previous year collected separately. Samples of fresh grass collected again in Oct. Samples of heather collected in May and Oct. Samples of juniper, broom and bilberry taken and separated into leaves and stems.	Drying to constant weight of 105°C, then ground. 5 g samples were wet-ashed with HNO_3/H_2O_2. Pb, Bi and La added as carriers and Pb-210 and Po-210 precipitated as sulphides by passing H_2S into solution. Determination of Pb-210 and Po-210 not stated.	Not stated.	The data reported in this study are for plants growing in a German heather. Pb-210 and Po-210 were found to be at normal levels. This data cannot be used for modelling purposes at Canadian uranium mines.
Aquatic Animals(6)	Swanson et al. 1985	Invertebrates: Ekman grab at deeper "main" stations; dip net in shallow areas near shore. Stream insects by dip net (no number given). Once location was found repeated Ekman or dip net samples were taken, screened and sorted until a sufficient amount of material was obtained or "until time ran out". Invertebrate stomach contents of fish: collected in 3" x 5" gill nets.	Ra-226: nitric/perchloric acid digestion. Precipitation as $Ba(Ra)SO_4$ and alpha spectrometry. Total U: nitric/perchloric acid digestion and delayed neutron counting.	Not stated.	This study was conducted at two uranium mining areas in Canada (Elliot Lake, Ontario and Wollaston Lake, Saskatchewan). The data can thus be considered representative of conditions at uranium mining areas in Canada.

TABLE 2-1 (Cont'd)

Environ. Compartment	Citation	Data Collection Methods	Analytical Techniques	Replication	Representivity
Aquatic Animals(6)	Swanson 1982	Larger insects (i.e. caddisfly larvae or dragonfly naiads were collected with dip nets. Blackfly larvae were collected by scraping them off of rocks or ceramic tiles placed in water. Two creeks sampled: Tailings Creek (contaminated) and Fredette Creek (uncontaminated). Collected insects placed in distilled water for 6 hr. Forage fish taken with seine and traps. Whitefish and suckers taken by gill net in spring and fall.	Ra-226 determined by Ba-Ra-SO_4 co-precipitation method using alpha spectrometry (CANMET 1979). Pb-210 determined by extraction and measurement of Bi-210 and beta counting (CANMET 1979). Uranium determined by the fluorometric method if low, by neutron activation if levels high. Po-210 (in fish internal organs) by wet ashing (nitric-perchloric digestion) and silver deposition method using alpha spectrometry (CANMET 1979). Sample prep. usually involved ashing at 500°C except for insect samples.	Not stated.	This study was conducted at Beaverlodge Lake and Tailings Creek (areas influenced by uranium mining). Control (uncontaminated) areas were Milliken and Fredette Lakes and Fredette Creek. Concentrations of radionuclides in the aquatic insects and fish of Beaverlodge Lake and Tailings Creek can be considered representative of Canadian uranium mining sites.
Forage, Crops (4)	Sheppard and Thibault 1984	Over 500 g of fresh plant material per sample. Branches of coniferous and deciduous trees and shrubs collected by clipping with pruning shears. Mosses pulled by hand; lichens picked by hand or scraped off rocks. All samples manually cleaned of litter and adhering soil or rock particles. Samples oven dried at 90°C, then ashed at 525°C.	Not stated for plant material.	5 samples of each abundant plant species at each site.	This study was confined to natural uranium concentrations in native plants, collected from Nopiming Provincial Park, Manitoba, growing over a low-grade ore body. While the concentrations of uranium in the plants cannot be considered representative of plant growing in or over tailings, the study did find two important points which are applicable to modelling plant uptake of uranium at Canadian mining sites: (1) the best part of the

TABLE 2-1 (Cont'd)

Environ. Compartment	Citation	Data Collection.Methods	Analytical Techniques	Replication	Representivity
					plant to sample is older tissue (e.g. stems, twigs, wood), and (2) sampling can be carried out anytime regardless of season.
Forage, Crops (4) Animal Produce (5)	Garner 1971	Literature review.	None.	None.	The data presented in this publication are not representative of compartments and radionuclide concentrations at Canadian uranium mines.
Forage, Crops (4) Animal Produce (5)	Hill 1967	Literature review.	None.	None.	Values given in this review are not representative of compartments and radionuclide concentrations at Canadian uranium mines.
Forage, Crops (4)	Kirchman et al. 1966	Crops collected by hand from greenhouse and field study.	Ra-226: gamma spectroscopy. Bi-214 measured after Ra-226/Bi-214 equilibrium had been established.	Not stated.	This study represents the uptake of Ra-226 by several crops. Data generated by this paper can be representative of plant uptake of Ra-226 at Canadian uranium mine sites if soil conditions are not significantly different.
Animal Produce (5)	Ackerman et al. 1968	One lactating goat of mixed breed was used for experiment. A single dose of 4.2 mCi of Po-210 oxide was given to goat orally.	Tissues wet-ashed and analyzed for Pb-210.	None.	Tissue concentrations determined in this experiment may not be representative of tissue concentration of ruminant ingesting lower levels of Pb-210 over much longer period of time as would be the case at a uranium tailings site.

TABLE 2-1 (Cont'd)

Environ. Compartment	Citation	Data Collection Methods	Analytical Techniques	Replication	Representivity
Animal Produce (5)	Hill and Jaworowski 1961	Not stated	Samples of bone dry-ashed at 470-500°C using Pb-free nitric acid to dissolve ash. Nitric replaced with Pb-free HCl and Pb extracted with diethyl-ammonium diethyl-dithiocarbamate at pH 0.1. Total lead estimated colorimetrically using dithizone. Pb-210 estimated afterwards by low-back-ground beta counting of the daughter Bi-210 which was separated from stable lead with cupferron.	2 samples	The concentrations of Pb-210 in ox bone were found to be 10 times higher than in human bone. These background results, however, are not applicable to Canadian uranium mine sites.
Forage, Crops (4)	Straub et al. 1961	Not stated	Not stated	Not stated	This paper presented Ra-226 activities in cabbage, lettuce, tomatoes, corn, and apples previously determined by another investigator. The collections were made from the Colorado-New Mexico area in 1958-59. It is not stated as to whether these crops were influenced by uranium mining. As such, this data cannot be used for modelling related to Canadian uranium mines.

TABLE 2-1 (Cont'd)

Environ. Compartment	Citation	Data Collection Methods	Analytical Techniques	Replication	Representivity
Aquatic Plants (7) Aquatic Animals(6)	Johnson 1978	Not stated	Not stated	Not stated	This paper cites Ra-226 activities in plants and animals as collected and analysed by another investigator working at an unknown uranium mining-millions complex in the Western U.S. This data is not suitable for inclusion for modelling radionuclide pathways at Canadian uranium mines.
Animal Produce (5) Forage, Crops (4)	Whicker 1978	Not stated	Not stated	Not stated	This paper uses previously unpublished data on plant and animals collected at uranium mill sites in western Wyoming, U.S.A. to demonstrate that biological organisms have the potential to accumulate radionuclides (U-238, Ra-226, Pb-210, Po-210) from areas adjacent to uranium mills. However, lack of information concerning data acquisition and analytical techniques prevents any use of this data for modelling purposes.
Forage, Crops (4) Animal Produce (5) Aquatic Plants (7) Aquatic Animals(6)	Michelson et al. 1962	Drums of food and water that would have normally been eaten by a typical man in an American city were collected and analyzed. Samples from 25 American cities were collected.	Pb-210 determined by counting Bi-210; Ra-226 determined by radon emanation.	duplicates	Values given in this report are for people in American cities and are not representative for people living near uranium tailing sites.

TABLE 2-1 (Cont'd)

Environ. Compartment	Citation	Data Collection Methods	Analytical Techniques	Replication	Representivity
Animal Produce (5)	Ng et al. 1979	Continuous feeding of cow with Pb-210, Po-210, Ra-226 and U.	Not stated	Not stated	Transfer factors for these radioisotopes were determined for the purpose of predicting dose to man and can be used to represent transfer of Canadian uranium mine associated radionuclides.
Forage, Crops (4) Animal Produce (5) Aquatic Plants (7) Aquatic Animals(6)	Williams 1982	Literature Review for Ra-226	None	None	This review of the uptake and transfer of Ra-226 for all pathways is representative of a uranium tailings area.
Forage, Crops (4) Animal Produce (5) Aquatic Animals(6) Aquatic Plants (7)	Zach 1978	Computer model, FOOD II, computed concentrations of 221 radionuclides in foodstuffs and water resulting from a release of radioactivity. Input values from the literature.	None	None	Model (FOOD II) can calculate the concentrations of radionuclides in foodstuffs and water that are affected by contamination from a uranium tailings area. Dose to man can also be calculated.
Forage, Crops (4)	Osburn 1965	Literature Review	None	None	This 20 page article contains only one page devoted to "Levels of radioactivity concentrated in environments and biological materials." Background concentrations of radium (isotope unspecified) are given for several plant species.

TABLE 2-1 (Cont'd)

Environ. Compartment	Citation	Data Collection Methods	Analytical Techniques	Replication	Representivity
Forage, Crops (4)	Eisenbud and France 1984	Vegetation collected from area of naturally high radioactivity and processed as if it were for human consumption (i.e. peeled, washed, shucked, etc.)	Dry ashing followed by dissolution with conc. HNO_3. Primary separation of Th from sample matrix by coprecipitation with Ca-oxlate at pH 3, redissolved for ion exchange separation of Fe from Th. Following elution, stable Ce added as carrier for coprecipitation of Th. Precipitate filtered onto prepared Tuffryn filter dried and counted. Ra-226 by radon emanation method.	Not stated	Figures generated on Thorium content of plants very tentative. Ore outcrop has little uranium and much higher concentrations of thorium than ore bodies mined in Canada. Therefore concentration of radionuclides in plants not representative of Canadian uranium mining environments.
Forage, Crops (4) Animal Produce(5)	Gallegos et al. 1983	BIOTRAN was constructed primarily to fulfill several project objectives: 1) To model the movement of transuranium radionuclides through ecosystems within the study are; 2) to provide enough generality for extending its use to other areas; 3) to be capable of predicting both short and long-term cycling of transuranium radionuclides in a number of climatic regimes; and 4) to provide output which could be used in evaluating potential hazards to man from transuranium radionuclides as a result of waste storage and accidental releases. BIOTRAN consists primarily of 1) state variables - model elements that comprise the system structure (compartments); 2) driving variables - model elements which vary with time, affect flow at the pool material, but are largely independent of the system: and 3) intermediate variables - model elements which control or affect flow of pool material from one compartment to another.		None	Although not originally designed to represent tailings release of radionuclides, the model appears general enough for use in this area.

TABLE 2-1 (Cont'd)

Environ. Compartment	Citation	Data Collection Methods	Analytical Techniques	Replication	Representivity
Forage, Crops (4) Animal Produce(5)	Gallegos and Wenzel 1984	HUMTRN is a major module of BIOTRAN to integrate climatic, hydrologic, atmospheric, food crop and herbivore simulation with human dietary and physiological characteristics and metabolism of radionuclides to predict radiation doses to selected organs of both sexes in different age groups.		None	Model was developed for the prediction of uranium and plutonium around a nuclear weapons assembly plant in Amarillo, Texas, U.S.A. as the result of an accidental release of these radionuclides. The values given for uranium in food crops and animals as a result of an accidental release are not representative of conditions at Canadian uranium mine sites.
Aquatic Plants (7)	Kalin 1982	Ekman samples along transects in Nero Lake. Moss covering bottom of Nero Lake washed clear of sediments, pressed to remove excess water and wet weight determined. Moss was washed in distilled water (until rinse water was clean). Moss wash remains (i.e. greater than 250 mesh) dried and pulverized in Wiley Mill to 20 mesh and dried to constant weight. Terrestrial vegetation growing on tailings excavated with shovel for collection of roots with whole plant.	Ra-226 and Pb-210 not stated. Methods referenced to previous article for aquatic mosses. Terrestrial vegetation wet oxidized with with conc. HNO_3 at room temperature and 120°C for 48 hr. Digests to pH of 2.5, filtered and passed over cation exchanges resin prior to Ra-226 and Pb-210 analyses. Methods referenced in previous publication. Uranium in both aquatic and terrestrial plants by neutron activation analysis.	Not stated	The uptake of Ra-226, Pb-210 and Uranium by aquatic and terrestrial plants growing in tailings polluted lake and on surface tailings are representative of conditions which occur at Canadian uranium mining sites.

TABLE 2-1 (Cont'd)

Environ. Compartment	Citation	Data Collection Methods	Analytical Techniques	Replication	Representivity
All Compartments	Clemente et al. 1980	40 samples of a complete daily diet were collected in 6 different regions of Italy. 150 samples of tooth and bone were collected from subjects working in spas and non-uranium mines. About 20 samples of same tisue collected from general public.	Coprecipitation of Po-210 with MnO_2 after wet ashing of sample. Po-210 plated on silver disc and measured by solid state detection spectrometry. Pb-210 evaluated from Po-210 ingrowth in sample.	Not stated	This study is not representative of conditions at Canadian uranium mines.
All Compartments	Schuttelkopf and Kiefer 1980	Environmental samples taken from the southern Black Forest region in Germany for Ra-226 analysis.	Not stated	Not stated	Unknown. Paper does not mention if source of higher values were taken from uranium mining areas.
Surface Water (2) Groundwater (0)	Kiefer et al. 1980	257 drinking water samples were collected in Germany during 1977-1979.	Ra-226 measured using Lucos scintillation chambers. Rn-222 determined by liquid scintillation.	Not stated	This study is not representative of conditions at Canadian uranium mines.
Vegetated Soil (3) Forage, Crops, Browse & Lichen(4) Animal Produce (5)	Milosevic et al. 1980	Not stated in detail. Samples of beef, milk, cheese, grass and soil were collected in uncultivated mountainous regions of central Yugoslavia.	Not stated	Not stated	This study is not representative of conditions at Canadian uranium mines.

TABLE 2-1 (Cont'd)

Environ. Compartment	Citation	Data Collection Methods	Analytical Techniques	Replication	Representivity
Forage, Crops, Browse & Lichen(4) Animal Produce (5) Man (9)	Persson 1974	Samples of lichen collected yearly from 1882-1972. Samples of reindeer meat from 1966-1972. Human blood from 1966-1972. Study conducted in Sweden.	All samples wet ashed with conc. nitric acid. Po-210 deposited on silver discs and activity measured with silicon-surface-barrier detector. Pb-210 measured indirectly from Po-210. Stable Pb measured by atomic absorption.	Not stated	This study is not representative of conditions at Canadian uranium mines.
Forage, Crops Browse & Lichen(4) Animal Produce (5) Man (9)	Blanchard and Moore 1970	Human tissue, lichen and Caribou samples from Alaska.	Samples wet ashed in nitric and perchloric acid with deposition of Po-210 on silver discs. Counting with ZnS scintillometer. Pb-210 measured indirectly from Po-210. Ra-226 by radon emanation method.		This study is not representative of conditions at Canadian uranium mines.
All Compartments	Hamilton 1970b	Literature review	None	None	This study is not representative of conditions at Canadian uranium mines.
Groundwater (0)	Scott 1961	Groundwater samples were collected from three high Ra-226 bearing aquifers in USA; Upper Mississippi Valley, Kansas/Oklahoma, and southeastern Colorado.	Not stated	Not stated	Values are within range of groundwater from several Canadian uranium mill tailings.

TABLE 2-1 (Cont'd)

Environ. Compartment	Citation	Data Collection Methods	Analytical Techniques	Replication	Representivity
Forage, Crops, Browse & Lichen(4) Animal Produce (5) Aquatic Plants (7) Aquatic Animals(6)	Michelson 1961	Samples of total diet were prepared by home economists in 5 U.S. cities.	Samples were dried, homogenized, ashed and analyzed for Ra-226 by the radon emanation method.	Not stated	This study is not representative of conditions at Canadian uranium mines.
Atmosphere (1)	Hamilton 1970a	Air filter samples were collected from Sutton, U.K., and also during an ocean traverse from Belgium to Antarctica.	Fission track method for uranium with detection limit of 1×10^{-14} gram U.	Not stated	This study is not representative of conditions at Canadian uranium mines.
All Compartments	Verkhovskaya 1972	Literature review for uranium, radium, thorium.	None	None	This study is not representative of conditions at Canadian uranium mines.
Forage, Crops, Browse & Lichen(4) Animal Produce (5) Aquatic Animals(6) Man (9)	Hursh 1957	Cadavers were collected from Rochester, N.Y. Drinking water samples collected from 41 American cities. Milk, fish, beans, peas and beef samples collected from various locations in U.S.A. for Ra-226 analyses.	Human bodies: ashing and acid digestion of ash followed by sodium carbonate fusion. Solutions were sealed and radon gas was allowed to collect. Radon analyzed in an ionization chamber. Water: emanation of radon. Food: dry ashing, wet digestion of ash and emanation of radon.	Not stated	This study is not representative of conditions at Canadian uranium mines.
All Compartments	Parfenov 1974	Literature review of the Po-210 levels in all environmental compartments.	None	None	This study is not representative of conditions at Canadian uranium mines.

TABLE 2-1 (Cont'd)

Environ. Compartment	Citation	Data Collection Methods	Analytical Techniques	Replication	Representivity
Forage, Crops, Browse & Lichen(4) Animal Produce (5) Aquatic Animals(6) Aquatic Plants (7) Surface Water (2) Groundwater (0)	Welford and Baird 1967	Uranium intake measurements were made on average diets of New York City, Chicago and San Francisco residents. Random samples of water, air, bone, liver and urine were analyzed from these cities.	Wet ashing of samples, separation of uranium using ion exchange, and analysis by fluorimetry.	Not stated	This study is not representative of conditions at Canadian uranium mines.
Forage, Crops, Browse & Lichen(4) Animal Produce (5) Aquatic Animals(6) Aquatic Plants (7) Surface Water (2) Groundwater (0)	Muth et al. 1960	Various food, drinking water and different organs of the human body were collected in Germany for Ra-226 analysis.	Emanation method.	Not stated	This study is not representative of conditions at Canadian uranium mines.
All Compartments	Magno et al. 1970	Air and total diet samples were collected from 12 American cities for Pb-210 analysis.	Air filters ashed and counted for Bi-210. Total diet samples were analyzed for Po-210 after a suitable ingrowth period.	Duplicates	This study is not representative of conditions at Canadian uranium mines.
Atmosphere (1) Vegetated Soil (3) Forage, Crops, Browse & Lichen(4) Animal Produce (5)	Simmonds et al. 1979	Collection of transfer coefficients from the literature.	None	None	Although this study addresses food chain transport of fission products and transuranics, the methods used can be applied to areas near Canadian uranium mill tailings.

TABLE 2-1 (Cont'd)

Environ. Compartment	Citation	Data Collection Methods	Analytical Techniques	Replication	Representivity
Atmosphere (1) Vegetated Soil (3) Forage, Crops, Browse & Lichen(4) Animal Produce (5)	Garten 1978	Literature review.	None	None	This study describes the food chain transport of atmospherically deposited radionuclides and is representative of the effect of atmospheric releases of dry uranium mill tailings particles.
Animal Produce (5)	DiGregorio et al. 1978	Literature survey of 108 experiments dealing with radionuclide cycling in terrestrial animals. Po-210, Th-234, uranium and fission products were the radionuclides of concern.	None	None	This study is representative in the sense that radionuclide retention values are given for terrestrial animals affected by radionuclide contamination.
Aquatic Animals (6)	John 1985	Fish collected in 3"x5" gill nets, beach seine, and trap nets (Dunlop Lake only). Fish from Swanson etal 1985 study of invertebrates.	Not given. Analysis carried out by Saskatchewan Research Counsil.	Three skin/bone and three flesh samples per lake. These samples were composities of from 1 to 5 fish.	Four of the five lakes sampled were subject to impacts from uranium tailings. Levels of Ph-210, Th-228, Th-230 and Th-232 from the four lakes are representative of radionuclides in fish in lakes impacted by uranium mine tailings in Canada.

2.1.2 ENVIRONMENTAL PATHWAYS

Publications dealing with radionuclide pathways in the environment are summarized in Table 2-2. The pathways of radionuclide dispersion of concern in this report are:

- Groundwater to Forage, crops, browse and lichen (P04);
- Atmosphere to Forage, crops, browse and lichen (P14);
- Surface water to Forage, crops, browse and lichen (P24);
- Surface water to Animal produce (P25);
- Surface water to Aquatic animals (P26);
- Surface water to Aquatic plants (P27);
- Vegetated soil to Forage, crops, browse and lichen (P34);
- Forage, crops, browse and lichen to Animal produce (P45);
- Forage, crops, browse and lichen to Man (P49);
- Animal produce to Man (P59);
- Aquatic animals to Man (P69);
- Aquatic plants to Aquatic animals (P76);
- Aquatic plants to Man (P79);
- Sediment to Aquatic animals (P86);
  and
- Sediment to Aquatic plants (P87).

The greatest number of pathway studies available for review are concerned with the Vegetated soil to Forage, crops, browse and lichen pathway (P34). This pathway is perhaps one of the most critical for the potential mobilization of radionuclides at the plant root/soil interface, the incorporation and translocation within the plant, and the potential for the transfer of these radionuclides directly to man or to animal products consumed by man. The second greatest number of pathway studies available for review are concerned with the transfer of radionuclides from Forage, crops, browse and lichen to Animal produce (P45). This is also a critical pathway in terms of the transfer of radionuclides to man.

The remaining pathways (some of which are potentially critical given the expected food consumption patterns involving large quantities of wildlife, aquatic animals and plants in the areas of Canadian uranium mine sites) are generally much less studied.

The studies reviewed thus far were generally conducted for the following reasons:

- model development or model parameter development;
- assessment of parameters or transfer factors used in various models;
- investigation of factors affecting the transfer of radionuclides from one specific compartment to another;
- investigation of the distribution of a radionuclide or radionuclides released into the environment;
- investigations of the potential for detrimental human health effects due to the accidental release of radionuclides; and
- comparisons of uptake of different radionuclides.

In addition, there are several publications which present the conceptual framework (and some specific transfer coefficients) for the environmental distribution of a large number of radionuclides in the environment. The generic assessment of radionuclide movement in the environment as discussed in these papers is relevant to all the pathways of concern in this report. Thus, the column in Table 2-2 which designates the specific pathway(s) discussed in the citation under review contains the designation "All Pathways" for these specific documents.

Individual reports of pathway studies are generally not strong in the discussion of the assumption or assumptions used in the study. In many cases the assumptions are not stated and the justification for the study is left to the individual reviewing the data.

From the review of available papers, only those studies conducted at or with materials from Canadian uranium mining sites appear to be applicable for use in modelling the release and transfer of radionuclides from these operations. The generic assessments are, of course, helpful, but other data from uranium mines elsewhere in the worldcannot be applied due to differences in transfer coefficients caused by differences in environmental conditions.

Laboratory studies of single doses or multiple doses of radionuclides to ruminants for derivation of transfer coefficients are generally unrealistic in terms of the dose applied, the method by which the dose is applied, or the matrix in which the dose is applied. Only a few of these studies can be applied to Canadian uranium mine sites and then only as a "worst case" scenario.

Overall, the literature reviewed for both compartments and pathways can be categorized in the following fashion:

- literature which is site-specific to Canadian uranium mine sites;
- literature of a generic nature which is broad enough to include radionuclide movement at Canadian mine sites; and
- literature reporting results from sites or laboratories remote from Canadian uranium mine sites.

Little of the data reported in the latter category can be applied to modelling radionuclide movement at Canadian uranium mine sites.

TABLE 2-2

Literature Summary - Environmental Pathways

Environ Pathway	Citation	Description, Approach	Justification of Assumptions/Approach	Applicability
Vegetated Soil to Forage, Crops (P34) Forage, Crops to Animal Produce (P45)	Watson et al. 1983	Calculation of soil to plant, feed to milk and feed to meat concentration factors.	Authors calculated individual dietary intakes of Ra-226 for people living in zones of natural radioactivity.	Not specific to uranium mine tailings; related to phosphate mining in Florida, U.S.A.
Surface Water to Aquatic Animals (P26) Sediment to Aquatic Animals (P86)	Swanson 1985	Calculation of distribution coefficients and transfer coefficients from values taken from radiochemical analyses of environmental samples	Determination of most critical pathway.	Distribution and transfer coefficients give the range of probabilities of transfer of radionuclides from one compartment to the next. Critical pathway was: sediments to insects to forage fish to whitefish to man. Work is generally applicable to all uranium tailings and is specific to Canada.
Surface Water to Aquatic Plants (P27) Water to Aquatic Animals (P26) Water to Animal Produce (P25)	Lush et al. 1982	Population dose commitments calculated for various groups along waterway from uranium tailings to downstream to ocean.	The application of a single set of adsorption and food chain coefficients for length of waterway is questionable.	Contribution of Ra-226, Pb-210 and Po-210 through water and fish consumption pathways constitute almost all of population dose. Study is generally applicable to all uranium mine tailings and is specific to Canada.

TABLE 2-2 (Cont'd)

Environ Pathway	Citation	Description, Approach	Justification of Assumptions/Approach	Applicability
Forage, Crops to Man (P49) Animal Produce to Man (P59) Aquatic Plants to Man (P79) Aquatic Animals to Man (P69)	Klement 1965	Estimation of the daily radium intake from estimated food consumption patterns and estimated concentrations of radium in various foods.	Dietary intakes may not necessarily be similar to those people living near tailings areas.	The values used to calculate the uptake were from the literature (compiled from around the world) and are not applicable to uranium mining areas.
Vegetated Soil to Forage, Crops (P34) Forage to Animal Produce (P45)	McDowell-Boyer et al. 1979	Calculation of transfer coefficients from soil to plant considered only the Pb content in the portion of the crop that was edible.	Dietary Pb-210 concentrations were calculated for several food categories due to plant uptake alone. These values were compared with Pb-210 concentrations in food items measured in New York City. Predicted or calculated values were found to be higher than measured values by factors up to 5.	Root uptake of Pb-210 is more important than direct deposition onto plant surfaces with respect to dietary concentration. This information is generally applicable to plants growing on or near uranium tailings.
Aquatic Animals to Man (P69) Aquatic Plants to Man (P79)	Zach 1980a	Creation of interactive code (NEPTUN) which parallels FOOD III for the assessment of dose to man thrugh aquatic food chains.	Assumptions used in computed program are realistic for waterborne radionuclides which are in equilibrium with man and his food chains. All transfer coefficients were taken from existing literature with most recent values assumed to be the best available estimates.	Excellent source of information for generic and specific transfer coefficients for 211 radionuclides. Generally applicable to uranium milling.

TABLE 2-2 (Cont'd)

Environ Pathway	Citation	Description, Approach	Justification of Assumptions/Approach	Applicability
Vegetated Soil to Forage, Crops (P34) Forage, Crops to Animal Products (P45)	Zach 1980b	A review and assessment of transfer coefficients in the published literature.	For the determination of suitable transfer coefficients assumptions of equilibrium (i.e. steady state), and linearity were made and transfer coefficients assessed in terms of method of determination, variability, generic versus site-specific values, statistical aspects, and use.	Study was related to transfer coefficients employed in general equilibrium assessment models. Although specifically produced for nuclear installations, the general nature of the text and description of transfer coefficients has application to the disposal of uranium tailings associated radionuclides.
Forage Crops to Man (P49)	Kennedy et al. 1985	Evaluation of relevance of potential biological transport processes at low-level waste disposal sites (i.e. burrowing animals and plant translocation).	Assumption of uniform distribution of radionuclides throughout plant is questionable. Also questionable is assumption that above ground plant materials contribute radionuclides to soil surface equal to amount contained in annual aboveground biomass.	Study is site-specific for ingestion of contaminated food products (plants) from a western arid site. In view of this and the concerns regarding the assumptions, application of the data to uranium tailings site studies is deemed to be inappropriate.
Forage, Crops to Man (P49) Animal Produce to Man (P59)	ApSimon & Goddard 1983 (Chapter 5 only)	Description of relationship between air or ground contamination and human exposure.	Assumptions are justified only for releases (continuous) from nuclear power stations.	Not applicable to Canadian uranium tailings.

TABLE 2-2 (Cont'd)

Environ Pathway	Citation	Description, Approach	Justification of Assumptions/Approach	Applicability
Aquatic Animals to Man (P69) Aquatic Plants to Man (P79)	IEC Beak Consultants Ltd. 1983	Description of the development and use of a model of investigating transport of radionuclides through aquatic pathways away from a hypothetical uranium mill tailings disposal site for the calculation of dose commitments for several tailing management scenarios.	Assumption that present, water chemistry of lakes and population habits and densities will remain constant for next several millenia is wrong, but necessary (apparently) for purposes of dose commitment calculation.	This work is generic, but abstracted from an existing uranium mine in Ontario. As such, section 3 (Aquatic Transport System) and section 4 (Food Chain Model) are specifically applicable to uranium tailings in the Canadian Environment.
Surface Water to Aquatic Animals (P26)	Swanson et al. 1985	Computation of bioaccumulation factors for water/sediment invertebrate transfer of radionuclides from collected and analyzed samples.	Review of available information on water/sediment transfer to invertebrates revealed that data are scarce, non-uniform and poorly documented. This pathway is a potentially major route for the transfer of radionuclides to man near Canadian uranium mines.	Study areas were chosen based on the applicability to other uranium mine sites in Canada. This is the type of information which is needed (i.e. site specific data) for determining the impacts of uranium tailings at Canadian uranium mines.
Forage, Crops to Man (P49) Animal Produce to Man (P59) Aquatic Animals to Man (P69)	Beak Consultants Ltd. 1986	A survey of the food consumption by individuals in Uranium City, Saskatchewan.	A study which is part of the larger Gunnar Field Study. Assumptions are not stated.	The Gunnar Site is so isolated that information in report may not apply to other sites.

TABLE 2-2 (Cont'd)

Environ Pathway	Citation	Description, Approach	Justification of Assumptions/Approach	Applicability
Aquatic Plants to Man (P79) Aquatic Animals to Man (P69)	Thompson et al. 1972	Listing of concentration factors derived for edible plants, invertebrates and fish from both freshwater and marine environments.	Concentration factors based on extensive literature review of stable isotope concentrations in aquatic organisms and water and on experimentally determined concentration factors. Special effort was made to derive a concentration factor that would be representative of edible parts. Assumptions necessary for the derivation of concentration factors appear to be justified.	The concentration factors presented were derived as representative values for the main classes of edible aquatic organisms. As such, they can be used for estimating the dose to man (and other quantities) relating to the contamination of aquatic ecosystems by radionuclides from uranium mine tailings.
Forage, Crops to Animal Produce (P45)	Verkhovskaja et al. 1967	Determination of annual intake of Th, U, Ra into ground-dwelling birds of the Russian taiga.	Assumptions related to: 1) differences in the number of birds during summer and winter period; 2) content of radioactive elements in birds' rations and 3) difference in ratio composition and the content of radionuclides during snow and snowless period seem justified. However, authors applied "special methods of investigations" to establish day ration for ground-dwelling birds. "Special methods" were not described.	Annual intake of radionuclides for these organisms cannot be used for uranium tailing studies as the areas are very different and unspecified methods were used to obtain annual intake rates.

TABLE 2-2 (Cont'd)

Environ Pathway	Citation	Description, Approach	Justification of Assumptions/Approach	Applicability
Animal Produce to Man (P59)	Nelson and Rust 1967	Investigation of the metabolism of and discrimination against Ra-226 after ingestion.	All assumptions made during this study (physiological similarities between swine and humans, similar excretion patterns, and identical absorption of Ra-226 in both animals) appear to be valid.	While this study is not directly applicable to the P59 pathway, the data is important in its implications related to "absorbed dose" versus total intake which is outside the present scope of work.
Surface Water to Aquatic Animals (P26)	Stegnor and Kobal 1982	Investigation of Ra-226 and U in uranium mining area of Yugoslavia.	Assumption that uranium mining increases levels and role of radium and uranium in the aquatic environment is a realistic and justifiable assumption.	The ratios of radium-226 and uranium in fish/water described in this study are generally applicable to any uranium mining area.
Vegetated Soil to Forage, Crops (P34)	Marple and Potter 1982	Investigation of radium uptake by native and naturalized plants at inactive uranium mill sites in the southwestern U.S.A.	Assumptions of absorption of radium by plants growing on uranium tailings or soil covered uranium tailing as a significant dispersal mechanism in the environment are justified.	Although the radium content of native and naturalized plants growing at inactive uranium mill sites was significant, the extremely arid environment of this region precludes the use of this data for Canadian uranium mine sites.
Sediment to Aquatic Plants (P87)	Kalin and Sharma 1982	Uptake of Ra-226 and Pb-210 by cattails growing on 20 yr old tailing sites.	Because of the differences between the physico-chemical properties of soil and uranium tailings the uptake of radium by vegetation growing on tailings was assumed to be different from the uptake of radium by plants growing on soil. This assumption is justified.	Because this study was conducted at uranium mining sites located in the south central part of Ontario, the information is applicable to uranium mines in Canada, if cattails are present in significant amounts.

TABLE 2-2 (Cont'd)

Environ Pathway	Citation	Description, Approach	Justification of Assumptions/Approach	Applicability
Sediment to Aquatic Animals (P86)	Garten et al. 1982	Environmental chemistry and uptake of U in a former low-level radioactive waste settling pond at Oak Ridge National Lab.	The assumption that the comparative approach taken in these field studies will be useful in forecasting similarities and differences in the bioaccumulation of actinides is justified.	Although this study involved radionuclides other than uranium, the findings related to uranium uptake and transport to aquatic animals from sediments is generally applicable to uranium milling areas.
Vegetated Soil to Forage, Crops (P34) Forage, Crops to Animal Produce (P45) Animal Produce to Man (P59)	Rayno 1982	5 pCi/g concentration (all nuclides) was used to estimate radionuclide activity taken up by forage. Human intake of contaminated foodstuffs was converted into estimated dose rates to bone and soft tissue using dose conversion factors.	Not all pathways were considered. For example, the water to man pathway was not assessed, which is actually critical to the contributed dose. An overestimation of dose to man from food chain movement of tailings radionuclides may result because of very conservative assumptions (i.e. cattle grazed during winter and severe drought.	Calculated dose values would be applicable if all assumptions are correct (e.g. if Ra-226 concentration in soil at abandoned uranium mill sites does not exceed 5 pCi/g subsequent to remedial action such as burial).
Surface Water to Aquatic Plants (P27) Surface Water to Aquatic Animals(P26)	Thompson, et al. 1972	Concentration factors derived for edible plants, invertebrates and fish (freshwater and marine). Values based on extensive literature of elemental conc. in aquatic organisms and water and on experimentally determined conc. factors.	Concentrations of elements in freshwater (Ca) taken from measured values in the literature representative of ecosystems from which aquatic foods are derived. Emphasis also placed on average values determined from a large number of samples.	Although the data reviewed in this publication are taken from a variety of sources (including uranium mining areas) its emphasis on average values makes the use of the data justified only when more site specific (i.e. uranium mining related) data is not available.

TABLE 2-2 (Cont'd)

Environ Pathway	Citation	Description, Approach	Justification of Assumptions/Approach	Applicability
Vegetated Soil to Forage Crops (P34) Forage Crops to Animal Produce (P45)	Ng et al. 1978	Description of approaches used to derive transfer factors from the literature; presentation of recently updated transfer factors to terrestrial foods; Identification of systematics of derived factors; discussion of uncertainties in derived values and limitations in use.	Updating transfer coefficients which currently appear in U.S. federal regulatory guidelines is necessary for the accurate prediction of the environmental transport radionuclides to man.	While this publication is directed toward radionuclides of the nuclear fuel cycle, the discussion of the various approaches to the estimation of transfer coefficients (from forage, crops to animal products and from soil to crops) and the uncertainties and limitations discussed for these transfer coefficients apply also the uranium mining radionuclides.
Vegetated Soil to Forage, Crops (P34) Forage, Crops to Animal Produce (P45)	Hoffman et al. 1978	Identification of uncertainty associated with model predictions as estimated by an analysis of statistical properties of input parameters.	It is necessary (i.e. justified) to assume the conceptual structure of a model is correct (i.e. correct input values will produce correct output values) and that the available data for input are representative of the true distribution of parameter values.	Although this publication is directed toward radionuclides associated with fission reactions, the discussion related to the analysis of the statistical properties of input parameters can be applied to uranium mine associated radionuclides as well.
Sediment to Aquatic Plants (P87) Surface water to Aquatic Plants (P27)	Havlik, 1967	Cumulation factors of Ra-226 with respect to water/aquatic plants and sediment/aquatic plants as determined by radiochemical analysis.	Aquatic organisms living in streams polluted by radioactive waste waters from the mining and processing of uranium ore have increased concentrations of Ra-226. This assumption is justified.	The information contained in this published paper, although old, is generally applicable to uranium mining in Canada.

TABLE 2-2 (Cont'd)

Environ Pathway	Citation	Description, Approach	Justification of Assumptions/Approach	Applicability
Forage, Crops to Animal Produce (P45)	Shor and Fields 1980	Re-examination of forage consumption parameters: 1) total daily feed, 2) fraction of feed from pasture and 3) fraction of year that cow is on pasture.	U.S. Nuclear Regulatory Commission recommendations concerning feed consumption refer to work done between 1959 and 1964. Since that time average milk production per cow has increased by 45%. This increase in milk production requires an accompanying increase in feed intake. Thus, the original recommendations are not based on inaccurate values for feed consumption parameters.	The document does not specifically discuss any radionuclide, but is primarily concerned with the consumption of feed (i.e. forage) by milk producing cows. As such, this information is generally applicable to North American dairy herds and the transport of any radionuclide through the forage to milk to man pathway.
Atmosphere to Forage, Crops (P14) Forage, Crops to Man (P49)	Yuan and Roberts 1982	Sources and exposure pathways associated with transport of radon and thoron gases and particulate materials containing uranium, thorium and their decay products from reference uranium and thorium mills are described.	Principal pathways addressed in this publication: 1) direct, external exposure to radionuclides in air, on ground; 2) inhalation of radioactive gases or particles; 3) ingestion of radioactivity in foodstuffs are justified. However, the dose to man using the Uranium Dispersion and Dosimetry (UDAD) computer code assumes a specific set of principal operating characteristics of the model mills. Deviation from these operating characteristics would invalidate the assumptions.	The Uranium Dispersion and Dosimetry (UDAD) computer code would seem to be applicable to all uranium mining sites. However, the data in the paper is for a model mill with a specific set of operating parameters that would not be applicable to other mills with significantly different operating parameters.

TABLE 2-2 (Cont'd)

Environ Pathway	Citation	Description, Approach	Justification of Assumptions/Approach	Applicability
Vegetated Soil to Forage, Crops (P34)	Ibrahim et al. 1982	Determination of Ra-226 and Po-210 concentrations in soil and native plants from various sites around a conventional acid leach uranium operation in western U.S. and estimation of plant/soil concentration ratios.	Although the vast majority of tailings are adequately confined and controlled, experience indicates elevated levels of associated radioactivity in soil, water, and biota immediately adjacent to areas where ore and tailings are stored.	The concentration factors determined for this study are for semi-acid land dominated by a grassland-sagebrush community and would not be applicable to Canadian uranium mines.
Surface Water to Aquatic Plants (P27) Surface Water to Aquatic Animals (P26)	Hesslein and Slavicek 1984	Four lakes in the Experimental Lakes Area in northwestern Ontario had known amounts of Ra-226 added during 1970-78.	None. Original purpose of Ra-226 additions was for studying gas exchange with Rn-222 (gaseous daughter product of Ra-226). However, Ra-226 was so rapidly removed from the water that the purpose was changed to look at partitioning of Ra-226 in lakes as might be applied to uranium mining and nuclear waste materials.	The findings of this study are generally applicable to any Ra-226 additions to aquatic systems (by whatever means). Since the site of these investigation is northwestern Ontario, the bioconcentration factors are generally applicable to Canadian uranium mines.
Surface Water to Aquatic Animals (P26)	Poston 1982	Preliminary study to determine if uptake of uranium and thorium occurs at significant rates in rainbow trout. Assessment of soluble and particulate partitioning behaviour of these radionuclides.	Study cites continued use of uranium and potential use of thorium as reactor fuels which may result in increased amounts of these radionuclides in the aquatic ecosystem. Assumption appears justified if nuclear power plants increase in abundance.	The concentration factors for rainbow trout observed for uranium and thorium are generally applicable to any aquatic environment.

TABLE 2-2 (Cont'd)

Environ Pathway	Citation	Description, Approach	Justification of Assumptions/Approach	Applicability
Vegetated Soil to Forage, Crops (P34)	Baes 1982	Determination of distribution coefficients (Kd) from existing literature values of soil-plant concentration ratios.	Existing models used to predict doses from environmentally released radionuclides usually do not account for loss from root zone by leaching. Leaching has been demonstrated to be important in radionuclide removal. The most important parameter in the modelling of radionuclide removal by leaching is the distribution coefficient (Kd).	Although the concept of radionuclide removal by leaching from the soil may be significant in terms of model applications for radionuclide pathways, the correlation between concentration ratios (CR) and Kd's does not appear to be sufficiently good (i.e. 0.68) for elements in general. Kd's for Pb, Po, Th, U extracted from existing literature are given, but their applicability to Canadian uranium mining is unknown.
Forage, Crops to Animal Produce (P45)	Garten et al. 1981	Comparison of the uptake of U-238, Th-232 and P-239 by small animals living on a floodplain contaminated by fission products, in eastern Tennessee, U.S.A.	Determination of the environmental mobility of these radionuclides to assess this hazard to wildlife and people.	This information is not applicable to Canadian uranium mine sites.
Surface Water to Aquatic Plants (P27)	Havlik 1971 and Havlik and Robertson 1971	Laboratory study of the uptake (by adsorption and absorption) of Ra-226 by unialgal cultures of green and blue-green algae.	Justification of approach resides in the known contamination of aquatic environments by uranium mining and milling and the relative hazard of Ra-226 to people.	Although the specific numbers (i.e. concentration factors) developed during this study are probably not applicable, the general findings are applicable to Canadian uranium mining sites. These are: 1) factors responsible for radium accumulation were adsorption, absorption and incorporation in order of importance; 2) the radium absorbed was inversely proportional to the concentration of radium in the water.

TABLE 2-2 (Cont'd)

Environ Pathway	Citation	Description, Approach	Justification of Assumptions/Approach	Applicability
All Pathways	Whicker & Schultz 1982a	Introduction to commonly used methods of quantitatively predicting radionuclide transport.	Development and use of radionuclide pathway models requires conceptual understanding and mathematical formulation of physical, chemical and biological processes which effect radionuclide movement in the environment.	The material and concepts presented in the chapter apply to pathway models developed for uranium mines in Canada.
All Pathways	Whicker & Schultz 1982b	Discussion of general concepts and apparent regularities regarding behaviour of specific radionuclides or groups of radionuclides.	Justification of the approach resides in the apparent similarities which ecosystems cycle specific groups of radionuclides.	The material and concepts presented in the chapter apply to pathway models developed for uranium mines in Canada.
Atmospheric to Forage, Crops (P14)	Elias, et al. 1978	Deposition sampling on vertical and horizontal, artificial surfaces and leaf and woody plant surfaces to measure atmospheric inputs of Pb to a remote subalpine ecosystem.	The assumption that deposition of elements surfaces having intimate contact with the food chain as an important method for the introduction of contaminants into food chains is justified.	While the data generated in this study is applicable to remote subalpine environments, it would not be applicable to areas impacted by particulate or aerosol emissions from uranium mines.
Surface Water to Aquatic Plants (P27)	Justyn and Stanek 1974	Study of Ra-226 and uranium accumulation in stream vegetation as influenced by uranium ore mining and milling in Czechoslovakia.	Concern for the accumulation of Ra-226 and uranium in sediments and aquatic plants of streams receiving uranium mining and milling wastes.	Concentration coefficients for aquatic plants are not given nor are they derivable from the information presented. Instead, graphical presentations are made of the relation between radionuclides in sediment ash and the ash of various groups of aquatic plants. The data as presented would be difficult to use in any application to Canadian uranium tailings impacts.

TABLE 2-2 (Cont'd)

Environ Pathway	Citation	Description, Approach	Justification of Assumptions/Approach	Applicability
Surface Water to Aquatic Plants (P27)	Dusauskene-Duz and Polikarpov 1978	Determination of the levels of Pb-210 accumulated in algae and macrophytes.	The assumption that Pb-210 can be used as a marker to study stable lead pollution in a generic aquatic environment appears to be justified.	This study was conducted on natural lakes with natural background levels of Pb-210. As such it is not applicable to modelling the impact of Canadian uranium mines.
Surface Water to Aquatic Plants (P27) Aquatic Plants to Aquatic Animals(P26) Sediment to Aquatic Plants (P87) Forage, Crops to Animal Produce (P45)	Mahon 1982	Delineation of the uptake and transport of naturally occurring radionuclides (U, Ra-226, Pb-210, Po-210) through aquatic and terrestrial food chains in an area of high natural radioactivity.	The assumption that studies of naturally occurring high concentrations of radionuclides could produce information generally applicable to the impact of uranium mines seems justified.	The information derived from this study is generally applicable to uranium mine sites in Canada.
Surface Water to Aquatic Plants (P27)	Anderson et al. 1961	Detailed studies of the effects of waste discharges from a uranium ore refinery on the aquatic biota of a western U.S. river.	This study was part of a more comprehensive pollution investigation to provide the basis for subsequent control of the waste discharges. Estimates of the concentration factor for Ra-226 in live attached algae based on assumed relationship between live weight and the resulting ash actually analyzed. This assumption may be justified for the specific river from which the alga sample was taken, but is open to question for the lakes of Canada normally impacted by uranium mines.	This concentration factors derived for this study cannot be applied to Canadian uranium mining sites. More site specific data is available.

TABLE 2-2 (Cont'd)

Environ Pathway	Citation	Description, Approach	Justification of Assumptions/Approach	Applicability
All Pathways	Coughtrey & Thorne 1983	Discussion of the general principles and concepts involved in radionuclide distribution and transport in terrestrial and aquatic ecosystems.	Many of the theoretical models derived from the study of radionuclides in ecosystems, have, because of their initial complexity, been simplified considerably. While this simplification can be useful, reliable results can only be obtained when the simplification is based on a sound knowledge of the initial complexity of the system under study.	The principles and concepts detailed in this book chapter are applicable to modelling the distribution and transport of radionuclides from Canadian uranium mine sites.
Vegetated Soil to Forage, Crops (P34)	van Dorp et al. 1979	Description of a new approach for the calculation of soil to plant concentration factors.	Most common approach for the calculation of concentration factors has several disadvantages: 1) lack of physical meaning of a concentration factor; 2) lack of a uniform method for determining concentration factors 3) where a concentration factor is used in a decision making process, it is relatively simple to set up an experiment demonstrating that the concentration factor is not accurate.	The parameters used to formulate the equation to describe the transfer of radionuclide from soil to plant are open to experimental determination, realistic estimation or a combination of both. Although intended for fission radionuclides, this method should also be applicable to soil and plant transfers at Canadian uranium mining sites.

TABLE 2-2 (Cont'd)

Environ Pathway	Citation	Description, Approach	Justification of Assumptions/Approach	Applicability
Surface Water to Aquatic Animals (P26)	Hubel et al. 1979	Presentation of accumulation factors for fish muscle as determined for 11 years in the area of a nuclear power station.	It was assumed to be too difficult to produce stringent mathematical equations to establish accumulation factors of individual radionuclides as a function of various parameters over a period of several years. It was likewise assumed that average accumulation factors would be more justified in describing conditions in the Danube River system over lengthy time periods. These assumptions appear justified.	The concentration factor derived from radium in this study is not applicable to Canadian uranium mine sites due to the location and concern with fission products only.
Vegetated Soil to Forage, Crops (P34) Forage, Crops to Animal Produce (P45)	Bunzl and Kracke 1984	Presentation of the distribution of Pb-210, Po-210, stable Pb and Cs-137 in soil and plants in a German heath.	From previous sampling and analyses, Cs-137 was always present in unusually high concentrations if samples were from a health. Review of gobal and regional Cs-137 fallout suggested enrichment of this radionuclide due to the special structure of the health ecosystem. Naturally occurring Pb-210 and Po-210 were also determined to assess if their distribution was unusually high.	Concentrations of Pb-210 and Po-210 in both the soil and vegetation of the health as well as the animals grazing on the health were considered normal (i.e. not elevated on a global scale), with the exception of Po-210 in sheep kidneys. The background levels of Po-210 and Pb-210 coupled with the site specific nature of this study does not make this data applicable to Canadian uranium mine sites.

TABLE 2-2 (Cont'd)

Environ Pathway	Citation	Description, Approach	Justification of Assumptions/Approach	Applicability
Forage, Crops to Animal Produce (P45)	Sansom and Garner 1966	Isotopes Ca-45 and Ra-224 administered simultaneously both orally and intravenously to two pairs of cows. Faeces, urine and milk monitored for these radionuclides for 8 days after dose.	Radium experiments were conducted as part of a larger program of work on fission products and to complete the series of alkaline-earth elements already studied.	Although this was a laboratory study using a radium isotope not normally associated with uranium tailings, important information relative to radium absorption and transfer to milk was obtained. In the absence of site specific data (i.e. for ruminant near uranium tailings sites) this information could be incorporated into a model for radium transfer from forage to milk.
Atmosphere to Forage, Crops (P14)	Chadwick and Chamberlain 1970	Solutions of Sr-85, Cr-21 and Pb-210 were sprayed onto grassland and the initial retention by the herbage and subsequent rate of field loss of weathering were measured.	Direct contamination of forage and crops can occur by radionuclides deposited from the atmosphere. In general, a considerable percentage of the deposited activity is retained initially on the foliage. With time, the retained activity decreases as a result of translocation and weathering. If radioactive decay is taken into account, the remaining processes are termed "field loss". The experiments described in this report were intended to investigate: 1) dependence of field loss on the physical and chemical nature of the radioactivity; and 2) the relative rates of loss in summer and winter.	Although not conclusive, the information presented appeared to show Pb-210 strongly retained on the foliage. This is supported by evidence from an earlier study on Pb-210. This information would appear to be useful when applied to Pb-210 dispersed from uranium mine tailing by the atmosphere.

TABLE 2-2 (Cont'd)

Environ Pathway	Citation	Description, Approach	Justification of Assumptions/Approach	Applicability
Forage, Crops to Animal Produce (P45)	Chapman and Hammons 1963	Description of the uranium content of cattle feed, milk, urine and faeces.	The metabolism of ingested uranium has been studied in various non-ruminant laboratory animals. Because the digestive processes of the ruminant is so different (from laboratory animals), the reported worked was conducted to define any differences between uranium metabolism in ruminants.	No evidence, was found that uranium metabolism in ruminants was different from non-ruminants. This information may be applicable to pathways of uranium transfer near Canadian uranium mines. Transfer coefficients developed for herbivors (i.e. plant to animal) may be used for ruminants and non-ruminants alike.
Vegetated Soil to Forage, Crops (P34)	Menzel 1965	Review of the published literature related to the uptake and possible concentration of radionuclides in plants.	Comparison of existing concentration factors for a number of elements derived from greenhouse and field experiments.	Conclusions from this study are generally applicable to transfer pathways of radionuclides at Canadian uranium mine sites. For example: 1) Concentration factors depend mainly on the chemical properties of the element, but may vary by one to two orders of magnitude depending on the chemical properties of the soil and species or plant part; 2) the role of plants in the movement of radionuclides in soil is minor except over very long periods of time.

TABLE 2-2 (Cont'd)

Environ Pathway	Citation	Description, Approach	Justification of Assumptions/Approach	Applicability
Vegetated Soil to Forage, Crops (P34)	Walters and Hansen 1970	Greenhouse study of vegetables grown in Po-210 oxide contaminated soils and calculation of transfer coefficients.	Possible entry of Po-210 into agriculture areas from an accidental release of fuel from large SNAP generators as a result launch pad abort, failure to attain orbit or re-entry from orbit. Data on transfer of isotope from soil to plant needed for this type of hazard analysis.	Soil used in study consisted of a mixture of Colorado alkaline (pH 7.6) brown soil (58% by wt.), sand (40% kg wt.), and sphagnum peat moss (2% by wt.). The transfer coefficients derived from this study would be stricty applicable to these soil conditions only. Application to Canadian uranium mine sites is unlikely.
Surface Water to Aquatic Animals(P26) Sediment to Aquatic Animals (P86)	Swanson 1982	The gathering of data on fish food organisms, sediments and fish from a lake which has received discharges from a uranium mill tailings treatment system for almost 30 yr. Comparison of this data with data from similar samples.	Data available to 1981 showed significant accumulation of radionuclides in organisms from aquatic systems affected by uranium mining. Existing data base (prior to 1981) did not include environments such as Beaverlodge Lake (i.e. northern Saskatchewan).	Concentration factors for sediment to insects not reliable due to small data base and high variability. Pathway from insects to fish not adequately investigated as most fish collected from lake whereas insects were collected from inflowing creeks. Water to Fish Pathway in lake appear to have sufficient database to justify calculation of concentration factors for this pathway. This latter data should be applicable to all Canadian uranium mines.
Vegetated Sol to Forage, Crops (P34) Surface Water to Aquatic Animals(P26)	Swanson and Abouguendia 1981	Literature review pertaining to the environmental conditions associated with abandoned uranium tailings in Saskatchewan.	Due to lack of regulations, uranium mining in northern Saskatchewan has resulted in the release of untreated uranium tailings into numerous lakes and release of radioactive and non-radioactive contaminants into the environment.	Although no concentration factors or compartment values are given in this document, it does give descriptions of three uranium tailings areas in northern Saskatchewan and general discussions of pathways by which radionuclides are dispersed into the environment.

TABLE 2-2 (Cont'd)

Environ Pathway	Citation	Description, Approach	Justification of Assumptions/Approach	Applicability
All Pathways	Battelle Mem. Inst. Pac. NW Lab 1980	Review and computer analysis of environmental data collected at three B.C. sites for the most probable pathways to biota and man of radionuclides released from a model uranium mine.	The Lt. Governor of the Province of B.C. ordered an inquiry to be made into the adequacy of existing measures to protect the environment and public during the course of developing the uranium industry in B.C. Environmental control technologies consistent with U.S. practice (and declared B.C. intent) was selected for model mill.	The model used in this report seems to be generally applicable to uranium mining in Canada. However, the specific assumptions used in the report (i.e. dilution of liquid releases, ingestion parameters for all organisms, etc.) are based on site-specific data in B.C. and thus are not applicable to all Canadian uranium mines.
Vegetated Soil to Forage, Crops (P34)	Sheppard 1980a	Literature review of radium and radon in soil-water-plant systems.	To assess the impact of radium and its daughter products on the environment, it is necessary to know their physical, chemical and biological behaviour in the environment.	In the absence of site specific soil to plant transfer coefficients for plants influenced by uranium mill tailings or tailings contaminated soil, the soil to plant transfer coefficients cited in this report could be used for specific plants (or plant types) in modelling the uptake of radium by plants at Canadian uranium mines.
Vegetated Soil to Forage, Crops (P34)	Sheppard 1980b	Literature review of uranium and thorium in soil-water-plant systems.	To assess the impact of man's use and disposal of uranium and thorium requires a knowledge of their physical, chemical and biological behaviour.	The information provided in this report is generally useful in modelling radionuclide dispersion from Canadian uranium mines. Not enough information is available concerning the derivation of the transfer coefficients presented in this report for their use in modelling.

TABLE 2-2 (Cont'd)

Environ Pathway	Citation	Description, Approach	Justification of Assumptions/Approach	Applicability
Surface Water to Aquatic Animals(P26)	Aoyawa and Inoue 1975	Generic demonstration of the aquatic food web as a series of compartments model. Concentrations of radionuclides in each compartment were estimated by numerical calculations and the degree of the influence of parameter variances on the concentration in organisms was evaluated.	Assumption that uptake kinetics of radionuclides by aquatic organisms can be generally expressed by first order ordinary differential equations is in doubt (as expressed by authors). Effects of stable elements antagonistic to or of similar chemistry to the radionuclide are assumed to be insignificant in model (a doubtful assumption in the real-world).	The results of the model presented in this paper confirms the need to collect information on the structure of a specific pathway, organism rations, assimilation rates, and environmental factors affecting the concentration of radionuclides through the food to estimate and evaluate the redistribution of radioactivity in the aquatic ecosystem. This paper is applicable to Canadian uranium mining in general in the manner of its conclusions. However, due to some of its questionable assumptions the model presented would seem inappropriate.
Vegetated Soil to Animal Produce (Simulated) (P34)	Ackerman et al 1968	Lactating goat was administered an oral dose of Po-210 oxide and transfer coefficient was estimated and Po-210 concentrations in various tissues determined at 20 days post-ingestion.	The assumption that tranfer coefficients for radionuclides from food to animal tissue can be simulated by or single, acute oral doses of specific radionuclides appears justified for "worst case" scenarios.	Given the total Po-210 source concentration for the average diet of lactating ruminant, the concentration of Po-210 in the cow's milk can be determined. This data would appear to applicable to Po-210 transfer from feed to milk in areas influenced by elevated Po-210 levels in the vicinity of Canadian Uranium mines.

TABLE 2-2 (Cont'd)

Environ Pathway	Citation	Description, Approach	Justification of Assumptions/Approach	Applicability
Vegetated Soil to Forage, Crops (P34)	Kirchman et al. 1966	1) Greenhouse experiments for comparison of Ra-226 uptake by ryegrass from 5 different soils. 2) Field experiments on a sandy soil, the upper layer of which was artificially contaminated with various levels of Ra-226	Abstract of paper presented at meeting. No assumptions are stated, but the approach is justified based on the lack of knowledge of Ra-226 uptake by plants in 1966.	Overall, the study showed strong discrimination against Ra-226 in transfer from soil to plant. This information is directly applicable to Canadian uranium mine sites providing that soil conditions (e.g. Ca^{+2} content) are not significantly different from those used in the study.
Vegetated Soil to Animal Produce (P34)	Stanley et al. 1971	4 cows given oral doses of Pb-203 in feed and output of Pb-203 monitored in milk, urine, and feces.	The assumption of a cow consuming known concentrations of a radionuclide to produce a specific concentration of the radionuclide in its milk quantified by a transfer coefficient of 0.02% appears justified.	Pb-203 should behave in a similar manner to Pb-210 and thus the transfer coefficients derived in this experiment should be applicable to Canadian uranium mine sites.
Forage, Crops to Man (P49) Animal Produce (P59) Aquatic Animals to Man (P69) Aquatic Plants to Man (P79)	Hill 1967	The importance of each pathway was determined by considering the intake data from water, food and air and assuming a 6% ICRP figure for absorption from the G.I. tract for Po-210.	Pb-210 and Po-210 occur as a normal constituent of human tissues in such amounts that the dose from Po-210 constitutes an important fraction of total background. Uncertainty exists concerning details of the mechanisms of radionuclide uptake by humans and the effects of dietary intake.	The findings of this paper does indicate the most important pathway for Pb-210 to man is via ingestion of food. However, no transfer coefficients are given making this work impossible to apply to tailings at Canadian uranium mines.

TABLE 2-2 (Cont'd)

Environ Pathway	Citation	Description, Approach	Justification of Assumptions/Approach	Applicability
Forage, Crops to Animal Produce (P45) Forage, Crops to Man (P49) Animal Produce to Man (P59) Animal Produce to Man (P59)	Garner 1971	Collection of results and findings from previous studies on pathways.	Review attempts to examine the sources species and quantities of radionuclides which may enter the biosphere, to explain how they may be distributed and to indicate by what mechanisms they may enter animals and man.	Various pathways are discussed for many radionuclides, mainly fission products. Although some discussion is given on the uranium-series radionuclides, no mention was given on uranium mine tailings. Transfer coefficients in this study for uranium tailings radionuclides could be used if their source was adequately assessed for use in a uranium mine tailings environment.
Vegetated Soil to Forage, Crops (P34)	D'Souza and Mistry 1970	Red kidney beans grown in nutrient solution. Th-230, Ra-226, Pb-210 and Po-210 added in carrier free state at activity level of 0.25 Ci/L.	Statement that "no quantitative data are available on their" ... (the radionuclides in the study) ..." entry and translocation measured under closely comparable conditions" appears justified.	The uptake of radionuclides by plants from nutrient solutions is much greater than uptake from soil. This work cannot be applied to uptake of radionuclides from uranium tailings.
Vegetated Soil to Forage, Crops (P34)	Dreesen et al. 1978	Goal of study was to establish vegetation on tailings or cover material without irrigation, soil amendments or continuing maintenance.	Projected demand for uranium fuel (in 1978) required expansion of uranium mining and milling with a subsequent increase in the amount of tailings in the environment. Revegetation studies at inactive tailings will assist in the quantification of radionuclide transport from tailings into plant material.	The tailings and test plots used in this study were in the arid southwestern U.S. (Grant's Mineral Belt - New Mexico). The data obtained from this study cannot be applied to Canadian uranium mine sites due to the large differences in climate (especially rainfall).

TABLE 2-2 (Cont'd)

Environ Pathway	Citation	Description, Approach	Justification of Assumptions/Approach	Applicability
Vegetated Soil to Forage, Crops (P34)	Whicker 1978	A general discussion of biological interactions (e.g. plant uptake, excavation by burrowing animals) and buried (capped) uranium mill tailings in relation to isolation of the tailings from the environment.	In 1978 most efforts to isolate uranium mill tailings were directed at geological and hydrological considerations related to engineering design and practice. Reclamation practices (required by law) include the establishment of biotic communities for long-term stablization. However, the intricacies and problems resulting from biological interactions are not well understood or quantified.	While the general concepts discussed discussed in this paper are relevant to all uranium tailings, the specific data presented are taken from Wyoming, USA and cannot be applied to uranium tailings in Canada.
Groundwater to Forage, Crops (P04) Surface Water to Forage, Crops (P24) Forage, Crops to Animal Produce (P45)	Johnson 1978	A very short, general discussion of the potential for transport of Ra-226 in the water to forage to cow to milk pathway and the inclusion of this route in the dose assessment from uranium mill tailings seepage.	Consideration of food chain transport of radionuclides as a significant pathway (along with inhalation of Rn-222 and exposure to Ra-226 progeny in tailings) is justified.	The short discussion of the food chain pathway is directed toward the uptake of radionuclides by forage from either ground or surface water contaminated by uranium mill tailings and is generally applicable to all uranium mine sites. The data presented are from an earlier publication concerning uranium minings in the western U.S. and are not applicable to Canadian uranium mines.

TABLE 2-2 (Cont'd)

Environ Pathway	Citation	Description, Approach	Justification of Assumptions/Approach	Applicability
Vegetated Soil to Forage, Crops (P34)	Rayno et al. 1980	Investigation of forage species consumed by livestock, the concentration of U-238, U-234, Th-230, Ra-226, and Pb-210 in the plants, ratio of activity in roots/shoots and the uptake coefficient (plant-to-soil activity ratio) for each species.	Concern over the U-238 series radionuclides (originating at uranium milling operation) contamination of the forage to livestock pathway is justified.	This study was conducted at the Anaconda uranium mill in Bluewater, New Mexico in the arid southwestern U.S. The data generated, while conceptually interesting, cannot be specifically applied to Canadian uranium mines.
Forage Crops to Man (P49) Animal Produce to Man (P59) Aquatic Animals to Man (P69) Aquatic Plants to Man (P79)	Zach 1978	Computer model FOOD II provides selection of 14 food types, 13 diets and 221 radionuclides. Doses to man can be calculated for the total body and 6 internal organs.	The model is justified for taking into account contamination of foodstuffs by air and water.	This model is an important tool for regulatory agencies to assess or even predict the dose to man living near a uranium tailings site.
Forage, Crops to Man (P49) Animal Produce to Man (P59) Aquatic Animals to Man (P69) Aquatic Plants to Man (P79)	Michaelson et al. 1962	Diets from 25 American cities were analyzed for Pb-210 and Ra-226.	Justification for study based on the need for information on the intake of Ra-226 and Pb-210 at the background level.	The findings of this study are not applicable to Canadian uranium tailings areas.

TABLE 2-2 (Cont'd)

Environ Pathway	Citation	Description, Approach	Justification of Assumptions/Approach	Applicability
Forage, Crops to Animal Produce (P45)	Ng et al. 1979	Determination of transfer coefficient from feed to cow's milk. Approach involved continuous feeding of Pb, Po and U to cow.	The transfer coefficient values appear to be justified when comparing with the U.S. Nuclear Regulatory Commission regulatory guideline values. These comparisons are presented in this paper. The differences between the vaues are within a factor of 2.	Radiological assessments of dose to man from radionuclides released to the environment (as from uranium mill tailings) are generally made using mathematical models that require transfer factors as input parameters to predict the concentrations of radionuclides in foodstuffs. This study is applicable to uranium mine tailings impacts.
All Pathways	Williams 1982	A review of the biological uptake and transfer of Ra-226. Discussion of various models and transfer coefficient calculations.	The simple linear concentration factor model for the calculation of transfer coefficients is justified for the water to algae uptake system only. Of the other 12 uptake systems for which data was available, the assumptions of linearity on equilibrium were violated. Author suggests that a more serious attempt be made on the theoretical basis of Ra-226 uptake.	According to the author, there is some doubt in applying transfer coefficients as input parameters in dose models. Further, Ra-226 has been shown not to be the critical radionuclide. In addition to Ra-226, dose calculations from uranium tailings areas should also include the contributory effects from Th-230, Pb-210 and Po-210. This study is applicable to modelling efforts at Canadian uranium mine sites.
Forage, Crop to Animal Produce (P45)	Watters and McInroy 1969	Single dose administered to the rumen of a milk producing Holstein cow by means of a fistula. One litre samples at each subsequent milking taken for Po-210 analysis for 18 days.	Justification for experiment appears to be the potential for contamination of large areas by radionuclide electrical generators in space missions. Assumption that uptake of forage contaminated with Po-210 is the same as single dose of Po-210 chloride appears doubtful.	Although Po-210 is a radionuclide of concern in uranium mine areas, the data generated from this study is not applicable to Canadian uranium mine tailings causing low level long-term contamination to adjacent areas.

TABLE 2-2 (Cont'd)

Environ Pathway	Citation	Description, Approach	Justification of Assumptions/Approach	Applicability
Vegetated Soil to Forage, Crops (P34)	Osburn 1965	Brief summary of the worldwide distribution of naturally occurring radionuclides with emphasis on their occurrence in rocks and soils and their passage into plants.	The justification for this review appears to be the "scattered" nature of the data regarding the static and dynamic distribution of naturally occurring radionuclides and their possible effects on biota.	There is little data presented in this review. Much of it is of a background nature. The general concensus from the limited data is that in proceeding from soils to plants to animals, a step-wise reduction of one order of magnitude exists (generally). The data which is presented cannot be applied to Canadian uranium mining sites.
Forage, Crops to Man (P49) Aquatic Animals to Man (P69)	Okamoto 1980	Evaluation of the contribution of Pb-210 and Po-210 from coal burning (thermal power plant) to the total dose to Japanese living in the vicinity of a plant.	Coal burning is more effective (by several orders of magnitude) than radon emanation from the ground (or tailings) in producing Pb-210 and Po-210. Most thermal power plants in Japan are located by the sea wherein seafood has the potential to be contaminated. Leafy vegetables potentially contaminated by particulate emissions also form a large part of the Japanese diet.	The release of Po-210 and Pb-210 from coal fired thermal plants is so different from that of uranium mill tailings that the information in this paper cannot be applied to uranium mill tailings models.

TABLE 2-2 (Cont'd)

Environ Pathway	Citation	Description, Approach	Justification of Assumptions/Approach	Applicability
All Pathways	Dory 1981	Very brief outline of the history of uranium mining in Ontario and the basic regulatory approaches for the minimization of impacts from uranium mining and milling in Canada.	An overview of the regulatory approaches required for justifying new tailings facilities to be developed, especially in regard to the serious damage and contamination caused by unregulated mining in the 1950s.	This publication, although extremely short, does point out why so much data generated at uranium tailings sites in the U.S. are not applicable to the Canadian situation: All Canadian tailings are saturated with water. While this situation may decrease the amount of Rn-222 released from Canadian tailings, it also dramatically changes the subsurface conditions relative to plant roots systems. This information is generally applicable to Canadian uranium mine sites.
Surface Water to Aquatic Animals (P26)	Kornberg and Davis 1966	A general summary of radionuclides in freshwater food chains, including radium and uranium.	This paper is a chapter in a book dealing with radioactivity in the human diet.	This publication offers only a review of one experiment concerning the uptake of Ra-226 by aquatic snails and a very short summary of the work conducted on the aquatic communities of a river impacted by a western U.S. uranium mine. This information is of questionable value in uranium mining applications.
Vegetated Soil to Forage, Crops (P34) Forage, Crops to Animal Produce (P45)	Eisenbud and France 1984	A report of the first nine months of a study of thorium, uranium, rare earth elements, Ra-228 and Ra-226 from soil to farm animals.	Abnormally high concentrations of radium and thorium in the Morro de Ferro area of Brazil prompted investigation of possible health effects due to plant uptake and transfer to farm animals.	The investigation (incomplete in 1984) concerns a natural outcrop of rock with extremely high thorium and radium concentration. Concentration ratios or uptake factors reported in this publication are extremely tentative in view of the small data base. As such, they are not applicable to Canadian uranium mine sites.

TABLE 2-2 (Cont'd)

Environ Pathway	Citation	Description, Approach	Justification of Assumptions/Approach	Applicability
Vegetated Soil to Forage, Crops (P34) Forage, Crops to Animal Produce (P45)	Gallegos et al. 1980	BIOTRAN was constructed primarily to fulfill several project objectives: (1) To model the movement of transuranium radionuclides through ecosystems within the study area; (2) To provide enough generality for extending its use to other areas; (3) To be capable of predicting both short- and long-term cycling of transuranium radionuclides in a number of climatic regimes; and (4) To provide output which could be used in evaluating potential hazards to man from transuranium radionuclides as a result of waste storage and accidental releases. BIOTRAN consists primarily of: (1) State variables--model elements that compromise the system structure (compartments); (2) Driving variables--model elements which will with time, affect flow of the pool material, but are largely independent of the system; and (3) Intermediate variables--model elements which control or affect flow of pool material from one compartment to another.		Although originally designed for long-term releases from high-level nuclear waste sites or accidental releases (short-term) from nuclear power facilities, the model is general enough to be applied to uranium tailings.
Forage, Crops to Man (P49) Animal Production to Man (P59)	Gallegos and Wenzel 1984	HUMTRN is a major module of BIOTRAN to integrate climatic, hydrologic, atmospheric, food crop, and herbivore simulation with human dietary and physiological characteristics and metabolism of radionuclides to predict radiation doses to selected organs of both sexes in different age groups.		Model was developed for the prediction of uranium and plutonium around a nuclear weapons assembly plant in Amarillo, Texas, U.S.A. as the result of an accidental release of these radionuclides. As such, it is not applicable to Canadian uranium mining sites.

TABLE 2-2 (Cont'd)

Environ Pathway	Citation	Description, Approach	Justification of Assumptions/Approach	Applicability
All Pathways	Hoffman and Baes 1979	Report the results of a statistical analysis of the properties of the input parameters used in model predictions of routine releases from nuclear facilities.	The assumptions of critical importance are: (1) the available data for input parameters are respresentative of the true populations of parameter values; (2) the model parameters are statistically independent; and (3) the structure of the model is an appropriate simulation of reality. The validity of these assumptions could not be verified.	The input parameters reviewed are used in the food chain pathway models used by the U.S. Nuclear Regulatory Commission for accidental releases from nuclear facilities and are not applicable to Canadian uranium mining sites.
Vegetated Soil to Forage, Crops (P34) Forage, Crops to Animal Produce (P45) Forage, Crops to Man (P49) Animal Produce to Man (P59)	Kirchner et al. 1982	Paper describes a model developed to simulate the transport of fallout radionuclides from the Nevada Test Site (NTS) through agricultural food chains to man.	The reconstruction of estimated doses to residents of the region surrounding the NTS during the 1950's was initiated because of recent concerns about a possible relationship between nuclear fallout exposures and human cancer incidence. The radiation doses received by human tissue from ingestion of contaminated products could only be estimated through computational procedures because pertinent, direct, contemporary measures were not made at the time.	This model cannot be applied to Canadian uranium mines due to direct application to the NTS and fallout radionuclides.

TABLE 2-2 (Cont'd)

Environ Pathway	Citation	Description, Approach	Justification of Assumptions/Approach	Applicability
Vegetated Soil to Forage, Crops (P34) Forage, Crops to Animal Produce (P45) Forage, Crops to Man (P49) Animal Produce to Man (P59)	Kaye et al. 1981	Brief review of the development and application of mathematical models used to predict the terrestrial food chain transport of potentially important pollutants to human health.	A review of the types of models used in the assessment of nuclear and chemical pollutants is justified due to Oak Ridge's extensive experience in modelling.	This review is general enough to be applied to any modelling exercise including that involving deposition of radionuclides from Canadian uranium mill tailings.
Vegetated Soil to Forage Crops (P34)	Knight 1983	A review of soil and plant factors influencing uptake of radionuclides by plants are reviewed. In addition, data describing uptake of Ra-226, Pb-210, Po-210, Th-230, and U-238 are given for plants associated with abandoned radioactively contaminated sites in U.S.	During 1940's and 1950's U.S. agencies conducted programs resulting in radioactive contamination of various sites in the U.S. These sites decommissioned with state-of-the-art techniques existing at the time. However, recent radiological surveys confirm contamination still exists. This program (FUSRAP) initiated for purpose of decontaminating these sites to meet current criteria for the protection of public health. FUSRAP sites consist of waste by-products from uranium and thorium processing.	Data reviewed in this paper are applicable to Canadian uranium mining sites as much of the information is from these situations.

TABLE 2-2 (Cont'd)

Environ Pathway	Citation	Description, Approach	Justification of Assumptions/Approach	Applicability
All Pathways	Kanak and Miller 1980	A summary of progress to date (1980) in a project to identify models available for environmental radiological assessments, to evaluate model structure, simplifying assumptions and data bases, to estimate their uncertainties, and if possible to recommend models and parameters best suited to particular assessment situation.	This report is to serve as a guide to the literature for those involved with the use and application of environmental radiological assessment models.	This literature review is focused on model and parameters best suited to breeder reactor environmental radiological assessments. As a result, this paper has no applicability to Canadian uranium mining.
All Pathways	Miller et al. 1979	A summary of progress to date (1979) in a project to identify models available for environmental radiological assessments, to evaluate model structure, simplifying assumptions and data bases, to estimate their uncertainties, and if possible to recommend models and parameters best suited to particular assessment situation.	This report is to serve as a guide to the literature for those involved with the use and application of environmental radiological assessment models.	This literature review is focused on model and parameters best suited to breeder reactor environmental radiological assessments. As a result, this paper has no applicability to Canadian uranium mining.

TABLE 2-2 (Cont'd)

Environ Pathway	Citation	Description, Approach	Justification of Assumptions/Approach	Applicability
All Pathways	Clemente et al. 1980	Evaluation of Po-210 internal burden and relative dose to the Italian population and to those groups of subjects exposed to high radon and daughters in air concentrations in non-uranium mines and spas.	Spa workers and non-uranium miners had highest levels of exposure to radon and daughters. Smoking was found to be an important contributor to natural sources of Pb-210 and Po-210 contamination in man.	This study is not applicable to exposure to radionuclides in the Canadian uranium mining industry.
All Pathways	Schuttelkopf and Kiefer 1980	Environmental and radiological assessment of Ra-226 in the southern Black Forest region of Germany.	People living in the Black Forest region had body burdens below the 7.4 uCi Ra-226 animal intake limit (German Radiation Protection Ordinance).	This study is not applicable to dispersal of Ra-226 from Canadian uranium mines. No mention is given in paper of areas affected by uranium mining in Germany.
Surface Water to Man (P29) Groundwater to Man (P09)	Kiefer et al. 1980	An assessment of the hazards of natural environmental exposure to Ra-226 and Rn-222 using dose calculations.	The approach taken by this study was justified. Average yearly doses to critical organs were estimated at 0.003 mSr (Ra-226 for bone lining) and about 70 uSr for Rn-222 (stomach).	Although this study is not directly applicable to Canadian uranium tailings areas, it does provide dosimetric values in natural background areas for comparative purposes.
Forage, Crops to Man (P49) Animal Produce to Man (P59)	Milosevic et al. 1980	An investigation of the distribution of uranium, Ra-226, Pb-210 and Po-210 in the ecological cycles in the mountainous regions of central Yugoslavia.	The approach taken by this study was justifed. Distribution of uranium, Ra-226, Pb-210 and Po-210 in mountainous regions was no different from regions in other parts of the world which are subject to cultivation.	This study is not applicable to radionuclide dispersion from Canadian uranium mines.

TABLE 2-2 (Cont'd)

Environ Pathway	Citation	Description, Approach	Justification of Assumptions/Approach	Applicability
Atmosphere to Forage, Crops (P14) Forage, Crops to Animal Produce (P45) Animal Produce to Man (P59)	Persson 1974	A comparative study of the transfer of Pb-210 and stable Pb through the lichen-reindeer-man food chain was conducted by using a compartment model and the concept of fractional residence time.	The approach taken by this study was justified. A steady decrease in the Pb-210/Pb-stable ratio was observed after 1940. This was explained by a cumulative increase in alkyllead consumption in the country.	Although this study is not applicable to Canadian uranium mines, the methods used could also be used to examine the airborne transport of dry tailings derived contaminants.
Atmosphere to Forage, Crops (P14) Forage, Crops to Animal Produce (P45) Animal Produce to Man (P59)	Blanchard and Moore 1970	Investigation of increased tissue levels of Pb-210 and Po-210 associated with the consumption of caribou meat in Alaska.	Approach is justified as findings concur with earlier assumptions that caribou meat is the principal source of Po-210 for Alaskan residents.	This study is not applicable to the dispersion of radionuclides from Canadian uranium mines.
Forage, Crops to Man (P49) Animal Produce to Man (P59) Aquatic Plants to Man (P79) Aquatic Animals to Man (P69)	Hamilton 1970b	Compilation of literature values on the concentration of uranium in man and his diet.	The approach taken in this study is justified.	This study is applicable in the sense that background concentrations can be found and pathways for each radionuclide can be simulated.
Groundwater to Man (P09)	Scott 1961	Compilation of literature values on Ra-226 concentrations in highly mineralized aquifers in the U.S.A.	The approach taken in this study is justified.	This study is applicable in the sense that background concentrations can be found and pathways for each radionuclide can be simulated.

TABLE 2-2 (Cont'd)

Environ Pathway	Citation	Description, Approach	Justification of Assumptions/Approach	Applicability
Forage, Crops to Man (P49) Animal Produce to Man (P59) Aquatic Plants to Man (P79) Aquatic Animals to Man (P69)	Michelson 1961	Diet samples from 5 American cities were analyzed for Ra-226.	The approach taken in this study is justified.	This study is not applicable to Canadian uranium mining. Background values cannot be assumed to be the same as those of Canadian population living near a uranium mine.
Atmosphere to Man (P19)	Hamilton 1970a	Air filter samples collected from the northern and southern hemispheres were analyzed for uranium.	The approach taken in this study is justified. Authors found that various sources account for the observed uranium concentrations in air.	This study is not applicable to Canadian uranium mining.
All Pathways	Verkhovskaya et al. 1972	An attempt was made to determine the distribution of radium, thorium and uranium in all environmental compartments.	The approach was not justified. The findings and conclusions are very qualitative.	This study is not applicable to Canadian uranium mining.
Forage, Crops to Man (P49) Animal Produce to Man (P59) Aquatic Animals to Man (P69)	Hursh 1957	Samples of human cadavers, water and foodstuffs from American cities were analyzed for Ra-226. A qualitative approach was used to relate the important contributions of Ra-226 to the human body.	Approach was justified. Foodstuffs, rather than drinking water, was shown to be the most important source of ingested radium.	This study is not applicable to Canadian uranium mining.

TABLE 2-2 (Cont'd)

Environ Pathway	Citation	Description, Approach	Justification of Assumptions/Approach	Applicability
All Pathways	Parfenov 1974	Literature review on the Po-210 levels in the environment and in man. Data were mainly compiled from USSR sources.	Approach was justified. Po-210 reaches man predominantly through food, mostly with food of vegetable origin, with fish and to a lesser extent with meat.	This study is not directly applicable to areas affected by Canadian uranium tailings. However, the paper does provide an excellent review of information on Po-210 distribution in the environment and man.
Forage, Crops to Man (P49) Animal Produce to Man (P59) Aquatic Plants to Man (P79) Aquatic Animals to Man (P69)	Welford and Baird 1967	Estimates of the uranium intake and excretion levels were made for 3 American cities. Estimates were based on diet data and laboratory data of the uranium content in samples of bone, lung and urine.	Approach was justified.	This study is not applicable to Canadian uranium mining.
Forage, Crops to Man (P49) Animal Produce to Man (P59) Aquatic Plants to Man (P79) Aquatic Animals to Man (P69)	Muth et al. 1960	Measurements were made on the radium content of autopsy material and a large number of food and drinking water samples.	Approach was justified. The daily uptake of Ra-226 was calculated for a person residing in a non-uranium mining area.	This study is applicable to Canadian uranium mining in the sense of providing information as a contrast or control situation to intakes of Ra-226 in a uranium mining area.
All Pathways	Magno et al. 1970	Air and total diet samples from 12 American cities were analyzed for Pb-210 to assess the various routes of Pb-210 intake.	Approach was justified for the assessment of important routes for the intake of Pb-210.	This study is applicable to Canadian uranium mining as verification of the important routes for Pb-210 uptake by humans.

TABLE 2-2 (Cont'd)

Environ Pathway	Citation	Description, Approach	Justification of Assumptions/Approach	Applicability
Vegetated Soil to Forage, Crops (P34) Forage, Crops to Man (P49) Forage, Crops to Animal Produce (P45) Animal Produce to Man (P59)	Simmonds et al. 1979	A general summary of methods for modelling the transfer of radionuclides in the food chains to man. Although fission products and transuranics were the examples, the same methods can be applied to radionuclides of the U-238 and Th-232 series. The models are dynamic in nature.	The study is justified in its approach in demonstrating that the model can be used in making radiological assessments.	The model detailed in this study can be applied to areas affected to contamination from a uranium mill tailings area. The model is orientated more to atmospheric dispersion of radionuclides rather than by water dispersion.
Aquatic Plants to Man (P79)	Paschoa et al. 1980	Annual collective dose equivalents for populations of a Brazilian uranium mining area via the drinking water and food ingestion pathways were calculated as a function of the Ra-226 concentrations in the surface water.	The approach taken (making quantitative appraisals of detriment assocated with uranium mining through the concept of collective dose equivalent) was shown to be dubious. It was established that a quantitative assessment of collective dose equivalent can only be made when it considers varying parameters of population distribution, irrigation practices, agriculture production and food consumption with time.	The approach taken in this paper can be applied to Canadian uranium mine areas only if the recommendations mentioned are followed and applied.

TABLE 2-2 (Cont'd)

Environ Pathway	Citation	Description, Approach	Justification of Assumptions/Approach	Applicability
Vegetated Soil to Forage, Crops (P34) Forage, Crops to Man (P49) Forage, Crops to Animal Produce (P45) Animal Produce to Man (P59)	Garten 1978	Methods for predicting the food chain transport of atmospherically deposited radionuclides for uranium and thorium.	The approach taken is justified. Although the model predicts behaviour of uranium and thorium in food chains, it is very much dependent on the input values. At present, minimum and maximum input values that are given in this study provide for a "best case" and "worst case" estimate of dose to man.	The model developed is applicable to Canadian uranium mines in that it provides the means for simulations of food chain transport of airborne radionuclides from dry uranium mill tailings particles.
Surface Water to Animal Produce (P25) Forage, Crops to Animal Produce (P34) Aquatic Plants to Animals (P75)	DiGregorio et al. 1978	A compilation of assimilation coefficients, retention or biological half-lives and excretion rates for a wide range of species and radionuclides including Po-210, Th-234 and uranium from literature sources.	The approach taken was justified. A data base was created that compiled assimilation rates for various terrestrial animals.	This study is applicable to Canadian uranium mining as an understanding of the dynamics of radionuclide movement in food chains.

2.2 GENERAL STUDIES ON PROBABILITY AND QUANTITY OF TRANSFER

The probability and quantity of transfer of radionuclides of the uranium-238 series (i.e. the uranium mine associated radionuclides) within each pathway are given as transfer coefficients in Table 2-3. The transfer coefficient is the ratio of radionuclide concentration in the consumer (e.g. tissue or organism) to that in the source consumed (e.g. water or food products).

A review of these data indicates that the most probable dose to man exists for the food (vegetation and animals) to man pathway. A pathway analysis study in the Beaverlodge uranium mill tailings area by Swanson (1985) concluded that the most critical pathway of radionuclides to man was Source → Sediment → Aquatic Plants → Aquatic Animals → Man. The key variable affecting this pathway according to the Lush et al. (1982) study is the suspended particulate concentrations in the receiving aquatic system, the settling velocities of these particulates and the solid aqueous phase distribution coefficient associated with each radionuclide. Receiving waters with low values of suspended material thus pose a potentially higher risk of dose to man.

TABLE 2-3

Transfer Coefficients from Uranium Mine Contaminated Environments

Pathway/Reference	Ra-226	Pb-210	Po-210	U	Th
Surface Water to Aquatic Animals (P26) Swanson 1982					
Water to Blackfly Larvae (Tailings Cr.)	219	158		0.73	
Water to Caddisfly Larvae (Tailings Cr.)	5,862	16,000		5.4	
Water to Dragonfly Larvae (Tailings Cr.)	50	476		0.31	
Water to Backswimmer (Tailings Cr.)	833	444		3.5	
Water to Damselfly (Tailings Cr.)	7,500	1,333		0.59	
Water to Whole Lake Chub (Tailings Cr.)	400	400		2.2	
Water to Whole Lake Chub (Ace Cr.)	833	400		2.2	
Water to Whole Small White Suckers (Ace Cr.)	667	600		4.3	
Water to Whole Lake Chub (Lake)	67	20		0.69	
Water to Whole Small White Suckers (Lake)	593	234		2.7	
Water to Lake Whitefish Flesh (Lake)	5	16		0.09	
Water to White Sucker Flesh (Lake)	18	20		0.07	

TABLE 2-3 (Cont'd)

Pathway/Reference	Ra-226	Pb-210	Po-210	U	Th
Sediment to Aquatic Animals (P86) Swanson 1982					
Sediment to Blackfly Larvae (Tailings Cr.)	1.14	1.29		0.23	
Sediment to Caddisfly Larvae (Tailings Cr.)	1.56	0.62		0.59	
Sediment to Dragonfly Larvae (Tailings Cr.)	0.008	0.05		0.04	
Sediment to Backswimmer (Tailings Cr.)	0.13	0.06		0.48	
Sediment to Damselfly (Tailings Cr.)	1.25	0.19		0.02	
Sediment to Lake Chub (Tailings Cr.)	0.01			0.01	
Swanson et al. 1985 Surface Water to Aquatic Animals (P26)*					
Water to Midge Larvae (N. Saskatchewan)	833-3,333			600-5,200	
Water to Midge Larvae (N. Ontario)	217-16,333			76-3,889	
Water to Blackfly Larvae (N. Ontario)	11,040-13,713			2,240-2,627	
Water to Caddisfly Larvae (N. Saskatchewan)	200-5,125			200-1,941	
Water to Caddisfly Larvae (N. Ontario)	167-13,333			364-3,091	
Water to Dragonfly Larvae (N. Saskatchewan)	1,000-1,667			280-850	
Water to Dragonfly Larvae (N. Ontario)	167-3,333			37-1,236	
Water to Snails and Clams (N. Ontario)	1,428-3,333			59-7,059	

TABLE 2-3 (Cont'd)

Pathway/Reference	Ra-226	Pb-210	Po-210	U	Th
Sediment to Aquatic Animals (P86) *Swanson et al. 1985					
Sediment to Midges (N. Saskatchewan)	0.13-0.67			0.07-0.84	
Sediment to Midge Larvae (N. Ontario)	0.14-2.2			0.21-1.7	
Sediment to Blackfly Larvae (N. Ontario)	1.6 -2.5			4.0 -5.2	
Sediment to Caddisfly Larvae (N. Saskatchewan)	0.05-0.17			0.017-0.67	
Sediment to Caddisfly Larvae (N. Ontario)	0.09-4.4			0.17-0.90	
Sediment to Dragonfly Larvae (N. Saskatchewan)	0.05-0.13			0.005-0.07	
Sediment to Dragonfly Larvae (N. Ontario)	0.006-1.1			0.007-0.36	
Sediment to Snails and Clams (N. Ontario)	0.006-0.27			0.007-0.88	
Surface Water to Aquatic Animals (P26) Stegnar and Kobal 1982					
Water to Fish	137			1.6	
Sediments to Aquatic Plants (P87) Kalin and Sharma 1982					
Tailings to Cattail Pools	0.01-21	0.03-25			
Surface Water to Aquatic Plants (P27) Thompson et al. 1972					
Water to Aquatic Plants	2,500	200	2,000	0.4-0.7	1,500

TABLE 2-3 (Cont'd)

Pathway/Reference	Ra-226	Pb-210	Po-210	U	Th
Surface Water to Aquatic Animals (P26) Thompson et al. 1972					
Water to Crustaceans				60	
Water to Invertebrates	250	100	20,000	100	500
Water to Fish	50	0.5-150	6.7-4,500	2.0	30
Vegetated Soil to Forage, Crops (P34) Sheppard 1980a					
Soil to Ryegrass	0.53-0.71				
Soil to Purple Clover	0.32-0.54				
Soil to Barley	0.07-0.83				
Soil to Cabbage	0.31-0.75				
Soil to Carrot	0.29-1.02				
Soil to Beet	0.21-1.38				
Soil to Potato	0.024-1.07				
Soil to Pea	0.60-3.1				
Soil to Bean	LTO.1-0.36				

TABLE 2-3 (Cont'd)

Pathway/Reference	Ra-226	Pb-210	Po-210	U	Th
Vegetated Soil to Forage, Crops (P34) Sheppard 1980b					
Soil to Herbs, Shrubs and Trees				0.0001-0.02	
Soil to Mosses				0.6 - 325	
Soil to Snap Beans, Soybeans, Tomatoes					0.0001-0.007
Soil to Uncultivated Plants					0.001-0.42
Vegetated Soil to Forage, Crops (P34) Beak Consultants Limited 1986					
Soil to Cattails	0.0101	0.0352		0.0168	0.1173
Soil to Sedge	0.0035-0.0321	0.0300-0.0424		LT 0.004-0.0186	LT 0.045-0.08
Surface Water to Aquatic Plants (P34) **IEC Beak Consultants Ltd 1983**					
Water to Wild Rice	50	4	40	20	30
Surface Water to Aquatic Animals (P26) **IEC Beak Consultants Ltd 1983**					
Water to Fish	50	300	50	20	30

TABLE 2-3 (Cont'd)

Pathway/Reference	Ra-226	Pb-210	Po-210	U	Th
Surface Water to Animal Produce (P25) IEC Beak Consultants Ltd 1983					
Water to Moose	4.8	0.33	2.8	1.7	1.5
Forage, Crops to Animal Produce (P45) IEC Beak Consultants Ltd 1983					
Feed to Moose	0.0046	0.0035	0.033	0.0041	0.0024

* from contaminated and uncontaminated areas
LT = less than

2.3 LITERATURE CONCERNING FOOD CONSUMPTION IN CANADA

The literature concerning food consumption in Canada was examined to determine if sufficient information was available to categorize food consumption patterns near uranium mining areas. Of the several reports published by Health and Welfare Canada concerning food intake and nutrition, only the publication entitled "Food Consumption Patterns Report" (Nutrition Canada, 1976) identified patterns related to food consumption for different segments of the Canadian population. While this publication did identify mean daily intake of food groups (i.e. dairy products, wild game, meat, poultry, fish, eggs, etc.) for various physiological age groups, the sample of individuals surveyed for each age group was a composite of various groups from across Canada from areas both close to and remote from urban centres. As such, this data is not specific to groups living in areas of Canada which have experienced uranium mining activities.

Publications produced by Agriculture Canada (e.g. Agriculture Canada 1979, 1984) also do not provide sufficient information for use in determining the consumption of various food groups by populations potentially influenced by uranium mining activities.

PART 3

DATABASE DEFICIENCIES AND FURTHER DATA NEEDS

PART 3 - DATABASE DEFICIENCIES AND FURTHER DATA NEEDS

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3.1 EVALUATION CRITERIA

As a basis for highlighting deficiencies in the data available, the literature reviewed in Part 2 has been categorized in terms of its applicability to Canadian conditions and/or the apparent quality of the work carried out. The categories adopted here and the basis for allocation can be summarized as:

- Meets Criteria for Use:
    - Discussion is comprehensive, comprehensible, and indicates author understands topic;
    - Researcher shows demonstrated experience in field;
    - Analytical techniques (if applicable) are usually explained and appear adequate for purpose;
    - Results are expected to be directly applicable to expected Canadian conditions; and
    - Volume of data or degree of replication was not considered, since data is limited in most studies.
- Useful Back-up Information:
    - Generally from non-Canadian environments which would not be applicable to conditions here, or in which representativity is unknown; or
    - Otherwise of apparently good quality in terms of work carried out.

- Not Applicable or Quality Indeterminate:
  - Insufficient information given to judge quality of work; or
  - Not applicable due to different setting, radionuclides.

These criteria are undoubtedly subjective, but more stringent evaluation would be difficult due to the wide range of studies considered.

3.2 DATA BASE DEFICIENCIES

3.2.1 COMPARTMENTS

Table 3-1 summarizes the evaluation of the literature compiled in Table 2-1, and reveals that approximately 68% of the literature dealing with Ra-226, Po-210, Pb-210 and uranium cannot be considered representative of conditions at Canadian uranium mine sites. The data in this group are:

- not of sufficient quality;
- obtained from uranium mine sites which differ substantially from Canadian uranium mine sites;
- representative of background concentrations in areas remote from Canadian uranium mine sites; or
- are unknown as to their representivity.

Thirty-two percent of the literature reviewed contains compartmental data which could be used as representative of conditions existing at Canadian uranium mine sites. Not all of this data was from studies conducted at Canadian uranium mine sites. Approximately 13 non-mine site studies were judged to be of sufficient scientific credibility for the data to be used for modelling of radionuclide movement away from the mine site (given the existence of certain preset conditions).

There is a general deficiency in the published literature of site specific data for Canadian uranium mining areas for concentrations of radionuclides in all the compartments concerned in this study. However, the compartment Forage, Crops, Browse and Lichen (4) and the compartment Animal Produce (5) appear to be more deficient than the other two compartments (i.e. Aquatic Animals and Aquatic Plants). The lack of site specific data (and the range of values normally associated with a wide variety of site specific data), make the determination of the usefulness of generic data difficult if not impossible.

TABLE 3-1

Classification of Literature on Environmental Compartments

Environmental Compartment	Meets Criteria For Use	Useful Backup Information	Quality Doubtful or Indeterminate
(0) Groundwater		Scott 1961	Welford and Baird 1967 Kiefer et al. 1980 Muth et al. 1960
(1) Atmosphere	Simmonds et al. 1979 Garten 1978		Hamilton 1970a
(2) Surface Water			Kiefer et al. 1980 Welford and Baird 1967 Muth et al. 1960
(3) Vegetated Soil	Simmonds et al. 1979 Garten 1978		Milosevic et al. 1980
(4) Forage, Crops, Browse Lichen	Swanson 1985 Kirchman et al. 1966 Williams 1982 Zach 1978 Simmonds et al. 1979 Garten 1978	Dave et al. 1985 Rayno 1982 Rumble and Bjugstad 1986 Marple and Potter 1982 Blanchard 1967 Mahon 1982 Ibrahim et al. 1982 Holtzman 1966 Sheppard and Thibault 1984 Gallegos et al. 1980	Watson et al. 1985 McDougall-Boyer et al. 1979 Klement 1965 Hallden and Fisenne 1961 Kavalsky et al. 1967 Verkhovskaja et al. 1967 Kauranen and Miettinen 1967 Dean 1966 Havlik 1970 Hill 1960, 1967 Buneland Kracke 1984 Garner 1971 Straub et al. 1961 Whicker 1978

TABLE 3-1 (Cont'd)

Environmental Compartment	Meets Criteria For Use	Useful Backup Information	Quality Doubtful or Indeterminate
(4) Forage, Crops, Browse Lichen (Cont'd)			Michelson et al. 1962 Osburn 1965 Eisenbud and France 1984 Muth et al. 1960 Welford and Baird 1967 Hursh 1957 Michelson 1961 Blanchard and Moore 1970 Persson 1974 Milosevic et al. 1980
(5) Animal Produce	Williams 1982 Zach 1978 Simmonds et al. 1979 Garten 1978 DiGregoria et al. 1978	Rayno 1982 Lush et al. 1982 Mahon 1982 Holtzman 1966 Ng et al. 1979 Gallegos et al. 1980	Watson et al. 1983 McDowell-Boyer et al. 1979 Russel and Smith 1966 Klement 1965 Hallden and Fisenne 1961 Verkhovskaja et al. 1967 Kauranen and Mieltinen et al. 1967 Garner 1971 Hill 1967 Schreckhise and Watters 1968 Milosevic et al. 1980 Persson 1974 Blanchard and Moore 1970 Michelson 1961 Hursh 1957 Welford and Baird 1967 Muth et al. 1960 Hill and Jaworowski 1961 Whicker 1978

TABLE 3-1 (Cont'd)

Environmental Compartment	Meets Criteria For Use	Useful Backup Information	Quality Doubtful or Indeterminate
(5) Animal Produce (Cont'd)			Michelson et al. 1962 Gallegos and Wenzel 1984
(6) Aquatic Animals	Swanson 1985 Stegnar and Kobal 1982 Beak Consultants Ltd. 1986 Hesslein and Slavicek 1984 Swanson et al. 1985 Swanson 1982 Williams 1982 Zach 1978	Lush et al. 1982 Mahon 1982 Poston 1982 Justyn and Lusk 1976	Klement 1965 Russel and Smith 1966 Hallden and Fisenne 1961 Kovalsky et al. 1967 Pentreath et al. 1967 Martin et al. 1967 Anderson et al. 1961 Johnson 1978 Michelson et al. 1962 Michelson 1961 Hursh 1957 Welford and Baird 1967 Muth et al. 1960
(7) Aquatic Plants	Williams 1982 Zach 1978 Kalin 1982		Johnson 1978 Michelson et al. 1962 Muth et al. 1960 Welford and Baird 1967 Michelson 1961
All Compartments			Clemente et al. 1980 Schuttelkopf and Kiefer 1980 Hamilton 1970a Verkhovskaya 1972 Parfenov 1974 Magno et al. 1970

3.2.2 PATHWAYS

Table 3-2 summarizes the classification of data on environmental pathways. The review of the literature compiled in Table 2-2 for the pathways of concern in this document indicates that by far the greatest number of publications concerned the Soil to Forage, Crops, Browse and Lichen and the Forage, Crops, Browse and Lichen to Animal Produce pathways. The numbers of papers concerned with the remaining pathways are generally less than half of those concerned with the above. Most of these relate to:

- the transfer of radionuclides from surface water to aquatic animals or aquatic plants; or
- the transfer of radionuclides from forage, crops, browse and lichen, animal produce and aquatic animals to man.

Of the literature reviewed concerning uranium and thorium series radionuclides, approximately 50% was not applicable to Canadian uranium mining. The remaining 50% consisted of a small subset of publications directly concerned with Canadian uranium mining sites and a much larger subset of publications concerning modelling concepts, principles, rationales, and frameworks applicable to modelling radionuclide movement in any environment.

Specific deficiencies highlighted by this literature review include all pathways with the exception of P34 (Vegetated soil to Forage, Crops, Browse and Lichen) and P45 (Forage, Crops, Browse and Lichen to Animal Produce). Although studies on the P34 and P45 pathways stand out as being the most numerous among all pathways of concern in this literature review, the site-specific data collected on these pathways at Canadian uranium mine sites (abandoned and operating) is still relatively sparse and should be enhanced.

TABLE 3-2

Classification of Literature on Environmental Pathways

Environmental Pathway	Meets Criteria For Use	Useful Backup Information	Quality Doubtful or Indeterminate
P04 Groundwater to Forage, Crops, Browse, Lichen			Johnson 1978
P09 Groundwater to Man	Scott 1961		
P14 Atmosphere to Forage, Crops, Browse, Lichens	Yuan and Roberts 1982	Kiefer et al. 1980	Elias et al. 1978 Chadwick and Chamberlain 1970 Persson 1974 Blanchard and Moore 1970
P19 Atmosphere to Man			Hamilton 1970a
P24 Surface Water to Forage Crops, Browse, Lichen			Johnson 1978
P25 Surface Water to Animal Produce	DiGregorio et al. 1978	Lush et al. 1982	
P26 Surface Water to Aquatic Animals	Swanson 1985 Swanson et al. 1985 Stegnor and Kabal 1982 Hesslein and Slavicek 1984 Swanson 1982 Swanson and Abouguendia 1981	Lush et al. 1982 Poston 1982 Mahon 1982 Thompson et al. 1972	Hubel et al. 1979 Aoyawa and Inoue 1975 Kornberg and Davis 1966

TABLE 3-2 (Cont'd)

Environmental Pathway		Meets Criteria For Use	Useful Backup Information	Quality Doubtful or Indeterminate
P27	Surface Water to Aquatic Plants	Hesslein and Slavicek 1984	Lush et al. 1982 Thompson et al. 1972 Havlik 1971 Havlik and Robertson 1971 Mahon 1982	Havlik 1967 Vustyn and Stanek 1974 Dusauskene-Duz and Polikarpov 1978 Anderson et al. 1961
P29	Surface Water to Man		Kiefer et al. 1980	
P34	Vegetated Soil to Forage, Crops, Browse, Lichen	Kaye et al. 1981 Knight 1983 Zach 1980b van Dorp et al. 1979 Simmonds et al. 1979 Garten 1978 DiGregorio et al. 1978	Gallegos et al. 1980 McDowell-Boyer et al. 1979 Marple and Potter 1982 Rayno 1982 Ng et al. 1978 Hoffman et al 1978 Ibrahim et al. 1982 Baes 1982	D'Souza and Mistry 1970 Dreesen et al. 1978 Whicker 1978 Rayno et al. 1980 Osburn 1965 Eisenbud and France 1984 Kirchner et al. 1982 Watson et al. 1983 Bunzl and Kracke 1984 Walters and Hamen 1970
P45	Forage, Crops, Browse & Lichen to Animal Produce	Zach 1980b Ng et al. 1978 Shor and Fields 1983 Simmonds et al. 1979 Garten 1978	McDowell-Boyer et al. 1979 Rayno 1982 Hoffman et al. 1978 Mahon 1982 Garner 1971 Sansom and Garner 1966 Chapman and Hammons 1963 Ng et al. 1979 William 1982 Dorg 1981 Gallegos et al. 1980 Kaye et al. 1981	Watson et al. 1983 Verkhovskaja et al. 1967 Garten et al. 1981 Bunzl and Kracke 1984 Johnson 1978 Watters and McInroy 1969 Eisenbud and France 1984 Kirchner et al. 1982 Persson 1974 Blanchard and Moore 1970

TABLE 3-2 (Cont'd)

Environmental Pathway	Meets Criteria For Use	Useful Backup Information	Quality Doubtful or Indeterminate
P49 Forage, Crops, Browse, Lichen to Man	Zach 1978 Beak Consultants Ltd. 1986 Simmonds et al. 1979 Garten 1978	Kaye et al. 1981 Yuan and Roberts 1982 Garner 1971 Hamilton 1970b Muth et al. 1960	Michelson et al. 1962 Okamoto 1980 Gallegos and Wenzel 1984 Kirchner et al. 1982 Klement 1965 Kennedy et al. 1985 ApSimon and Goddard 1983 Hill 1967 Milosevic et al. 1980 Michelson 1961 Hursh 1957 Welford and Baird 1967
P59 Animal Produce to Man	Beak Consultants Ltd. 1986 Zach 1978 Simmonds et al. 1979 Garten 1978	Nelson and Rust, 1967 Garner 1971 Kaye et al. 1981 Hamilton 1970b Muth et al. 1960	Klement 1965 ApSimon and Goddard 1983 Hill 1967 Michelson et al. 1962 Gallegos and Wenzel 1984 Kirchner et al. 1982 Blanchard and Moore 1970 Persson 1974 Milosevic et al. 1980 Michelson 1961 Hursh 1957 Welford and Baird 1967

TABLE 3-2 (Cont'd)

Environmental Pathway	Meets Criteria For Use	Useful Backup Information	Quality Doubtful or Indeterminate
P69 Aquatic Animals to Man	Zach 1978 Zach 1980a IEC Beak Consultants Ltd. 1983 Beak Consultants Ltd. 1986 Thompson et al. 1972	Hamilton 1970 Muth et al. 1960	Michelson et al. 1962 Michelson 1961 Okamoto 1980 Klement 1965 Hursh 1957 Welford and Baird 1967
P75 Aquatic Plants to Animal Produce	DiGregorio et al. 1978		
P79 Aquatic Plants to Man	Zach 1978 Zach 1980a IEC Beak Consultants Ltd. 1983 Thompson et al. 1972	Garner 1971 Paschoa et al. 1980 Hamilton 1970b Muth et al. 1960	Michelson et al. 1962 Michelson 1961 Klement 1965 Hill 1967 Hursh 1957 Welford and Baird 1967
P86 Sediment to Aquatic Animals	Swanson 1982	Garten et al. 1982	
P87 Sediment to Aquatic Plants	Kalin and Sharma 1982	Havlik 1967	
ALL PATHWAYS		Dorg 1981 Williams 1982 Whicker and Schultz 1982a,b Battelle Mem. Inst. Pac. NW Lab 1980 Parfenov 1974 Magno et al. 1970	Kanak and Miller 1980 Miller et al. 1979 Hoffman and Baes 1979 Clemente et al. 1980 Schuttelkopf and Kiefer 1980 Verkhovskaya et al. 1972

3.3 USE OF GENERIC OR SITE-SPECIFIC DATA

One objective of this study was to highlight site-specific (or organism-specific) data which could serve a generic function, and conversely, generic data which could be used in place of site-specific data. This question raises some theoretical issues related to the modelling process itself, and the aims of that process.

It can be argued that:

- generic input data will result in the model producing a generic prediction - i.e. one that is low in precision but applicable to a range of different environmental conditions.
- site-specific input data will (other things being equal and assuming the model is correct) produce a site-specific prediction - i.e. one that is more precise and applicable to that site.

Under what conditions, then, would generic input data produce a site-specific prediction? In principle, this would be the case only in circumstances where one could be reasonably confident that the statistics of the generic data set (i.e. moments of the probability density function) would be comparable (in a statistical sense) to those of the site-specific data set. This review has identified no compartment where there is enough generic and/or site-specific data to show clearly that this is or would be the case. Although there are good studies, competently carried out, with valid data, probability density functions are not usually determined, and in most cases there is insufficient data to define these.

Could site-specific input data be used as the basis for a generic prediction? Again the answer would seem to be no - the prediction would be more precise than needed and might not cover the full range of values expected in the case where generic input data were used.

What, then, of the case where one has a combination of site-specific and generic data to use as input for the model? The prediction will fall somewhere in the middle, being neither as precise as the case using all site-specific data, nor as fully applicable to a range of conditions as the case using only generic data. In the absence of sufficient data to confirm the congruence of the two data sets, it is tempting for modellers to use generic data on a site-specific basis, particularly where the model's response is not sensitive to variation in that parameter. While this can be justified on grounds of economics and practicality, it should be recognized that difficulties in interpretation of the model predictions may arise, particularly if an accurate site-specific prediction is required.

The objective of modelling or simulating a complex system is to produce a prediction of some future state or quantity. If the goal is to produce a site-specific prediction, then site-specific input data will always be required for this purpose. Garten (1978) argued that "more realistic predictions can be achieved by direct measurement of parameter values in the field under conditions appropriate to the assessment at hand".

This study has identified numerous sources of data which could, as a group, be used to generate generic data. However, for any case where a site-specific prediction is required, site-specific input data will always be needed. In the context of uranium tailings in Canada, it is perhaps fortunate that the problem is confined to relatively few locations, and that the collection of site-specific data would therefore not be as onerous (logistically or financially) as might otherwise be the case. It should also be noted that our scientific knowledge of the source terms and initial physical dispersion processes (PS0, PS1, PS2) is more complete than that of the biological processes, interactions, and variability which are characteristic of the higher trophic levels. It is therefore possible that site-specific modelling may be most appropriate for the initial portions of the relevant food chains, and that modelling of higher trophic levels must, in the near future at least, be only carried out on a generic basis.

3.4 DATA NEEDS

Compared to the relatively large amount of scientific literature concerning the radionuclides Ra-226, Pb-210, Po-210, Th-230 and uranium, very little is specifically applicable to the compartmental concentrations of radionuclides or the transfer of radionuclides among compartments at Canadian uranium mine sites (abandoned and operating).

The concluding remarks in one particular published paper (Aoyama and Inoue 1975) examined in this literature review are worthy of note. This study involved a rigorous mathematical exercise designed to evaluate the degree of the influence of parameter variances on radionuclide concentrations in aquatic organisms. The conclusion of the paper was that data concerning:

- the structure of the food web;
- type and amount of food of organisms;
- assimilation rates of each radionuclide;
- the environmental factors which affect the concentrations of radionuclides in the compartments of the food web; and
- the environmental factors which affect the transfer of radionuclides among compartments

should be collected to properly evaluate the redistribution of radionuclides in the aquatic environment.

This conclusion is directly related to the NUTP mandate for constructing and running the computer model. If the model is to be an accurate reflection of the transfer of radionuclides from uranium tailings to man in Canada, then the data (and the factors affecting the data) used for input into the model must be determined in studies at Canadian uranium mine sites designed to fulfill the specific requirements of the model.

While the scientific literature (outside that directly concerned with Canadian uranium mine sites) may assist the development of model in terms of concepts, principles and framework, only data from Canadian uranium mine sites will provide for an accurate representation of model parameters and output.

There are a finite number of Canadian uranium mining sites (abandoned and operating). Obtaining specific data (e.g. plant uptake of radionuclides from tailings) for each site should give an indication of the range of values to be expected for input into a model which will cover the entire Canadian uranium mining industry.

Aggregation of compartments has been suggested as one way to obviate deficiencies in information related to transfer mechanisms. Aggregation usually leads to a decrease in realism of the simulation model and a loss of information. As aggregation increases, predictions become more general and verification is made more difficult. As a general principle, the structure of the model should represent the researcher's best attempt to describe reality. Further aggregation of compartments beyond the generalization of Figure 1-2 would serve no useful purpose and would appear to further restrict the applicability of the model.

3.5 GUIDELINES FOR FURTHER STUDIES

Further work, particularly in field data collection, is required to provide site-specific input data for modelling purposes. General guidelines for data collection should include:

- Collection of data should be keyed to model requirements. The literature reviewed consisted of studies concerned with uranium mining associated radionuclides in environmental compartments and movements in environmental pathways. With the exception of a very few cases, these studies were not conducted to supply data for the NUTP model. Further studies should be designed so that the data produced is that needed for the model being used. That is, the study design should reflect the model needs.

- Intensity of sampling should permit statistical treatment of data. Current modelling efforts centre on a probabilistic approach. Data should be adequate to permit calculation of the appropriate probability density functions.

- Analytical quality control should be an important focus of attention. This issue has previously received attention by the NUTP, and emphasis upon it should continue and even be strengthened.

REFERENCES

NOTE:

This reference list includes all documents reviewed for this study. Many were found to be non-applicable (usually due to irrelevant subject matter). Those marked with asterisks (*) were subjected to more detailed review and are cited in the text and tables of this report.

*Ackerman, R. A., R.O. Thomas, and W.V. Thayne. 1968. Internal distribution and milk secretion of ^{210}Po after oral administration to a lactating goat. Journal of Dairy Science 52:1867-1872.

Adams, W.H., C.W. Christenson and E.B. Fowler. 1965. Relationship of soil, plant and radionuclide. In: Radioactive Fallout, Soils, Plants, Foods, Man. E.B. Fowler (ed.), Elsevier Publishing Company, New York.

*Agriculture Canada. 1979. Handbook of Food Expenditures, Prices and Consumption. Edited and published by the Information Division, Agriculture Canada, Ottawa K1A 0C5.

*Agriculture Canada. 1984. Handbook of Food Expenditures, Prices and Consumption-Supplement. Edited by Communication Branch Agriculture Canada, Ottawa K1A 0C5.

Amiard, J.-C. and C. Amiard-Triquet. 1980. Le Transfert des Polluants Radioactifs dans les Chaines Alimentaires Aquatiques. Annals of Biology 19(2):117-146.

*Anderson, J.B. 1961. Effects of uranium mill wastes on biological fauna of the Animas River (Colorado-New Mexico). In: Radioecology. Proceedings of the First National Symposium on Radioecology held at Colorado State University, Fort Collins, Colorado, September 10-15, 1961. V. Schulz and A.W. Klement, Jr. (eds.).

Anochin, V.L., Ju. M. Svirezhev and A.N. Tjurjukanov. 1967. Mathematical model for migration of radiostrontium in soil. In: Radioecological Concentration Processes. Proceedings of an International Symposium held in Stockholm 25-29 April, 1966. B. Abert and F.P. Hungate (eds.), Pergamon Press, Toronto.

Anonymous. 1982. Field study on radionuclide migration. Chemiker-Zeitung 106(3):111-112.

*Aoyawa, I. and Y. Inoue. 1975. Estimation and evaluation of the Radioactive Contamination through a food web in a aqautic ecosystem (2). System analysis of the transfer of radionuclides through a food web. Journal of Radiation Research 16:132-141.

*ApSimon, H.M. and A.J.H. Goddard. 1983. Atmospheric Transport of Radio-Isotopes and the Assessment of Population Doses on a European Scale. Report prepared for the Commission of the European Communities. EUR 9128.

Aten, A.H.W., Jr., J.W. Dalenberg and W.C.M. Bakkum. 1961. Concentration of uranium in sea fish. Health Physics 5:225-230.

*Baes, C.F. 1982. Prediction of radionuclide K_d values from soil-plant concentration ratios. Transactions of the American Nuclear Society 41:53-54.

Baltakmens, T. 1974. Profiles of lead-210 and radium-226 in four New Zealand soils. New Zealand Journal of Science 17:435-439.

Barth, D.S. and M.S. Seal. 1967. Radioiodine transport through the ecosystem, air-forage-cow-milk using a synthetic dry aerosol. In: Radioecological Concentration Processes. Proceedings of an International Symposium held in Stockholm 25-29 April 1966. B. Aberg and F.P. Hungate (eds.), Pergamon Press, Toronto.

*Battelle Memorial Institute, Pacific Northwest Laboratories. 1980. Critical Biological Pathways for Transfer of Radioactive and Heavy Metal Contaminants to Biota and Man in Relation to Developments of the Uranium Industry in British Columbia. Final Report to the Royal Commission of Inquiry into Uranium Mining.

*Beak Consultants Limited. 1986a. Gunnar Field Study. Volume 9, Eating Habits of the Local Population. Report Prepared for National Uranium Tailings Program. Supply and Services Canada.

*Beak Consultants Limited. 1986b. Gunnar Field Study. Volume 7, Biology. Report Prepared for National Uranium Tailings Program. Supply and Services Canada.

Beard, H.R., I.L. Nichols and D.C. Seidel. 1979. Absorption of Radium and Thorium from Wyoming and Utah Uranium Mill Talings Solutions. Report by the U.S. Department of the Interior, Bureau of Mines. BUMINES-RI-8396.

Benes, P. 1982. Physico-chemical forms and migraton in continental waters of radium from uranium mining and milling. In: Environmental Migration of Long-Lived Radionuclides. Proceedings of an International Symposium on Migration in the Terrestrial Environment of Long-Lived Radionuclides from the Nuclear Fuel Cycle. Knoxville, Tennessee, USA, 27-31 July 1981. Published by the International Atomic Energy Agency.

Benes, P.L., L. Zvolanek and M. Cejchanova. 1985. Migration of lead-210 and stable lead in surface waters impacted by uranium mine wastes. Acta Hydrochimica et Hydrobiologia 13(6):655-667.

Bennett, B.G. 1975. Transuranic element pathways to man. In: Transuranium Nuclides in the Environment. Proceedings of the Symposium on Transuranium Nuclides in the Environment organized by the United States Energy Research and Development Administration and the International Atomic Energy Agency. Held in San Francisco, 17-20 November 1975.

Berström, S.O.W. 1967. Transport of fallout ^{131}I into milk. In: Radioecological Concentration Processes. Proceedings of an International Symposium held in Stockholm 25-29 April 1966. B. Aberg and F.P. Hungate (eds.), Pergamon Press, Toronto.

*Blanchard, R.L. 1967. Relationship between ^{210}Po and ^{210}Pb in man and his environment. In: Radioecological Concentration Processes. Proceedings of an International Symposium held in Stockholm 25-29 April 1966. B. Aberg and F.P. Hungate (eds.), Pergamon Press, Toronto.

Blanchard, R.L. and B. Kahn. 1973. The fate of radionuclides discharged from a PWR nuclear power station into a river. In: Environmental Behaviour of Radionuclides in the Nuclear Industry. Symposium Proceedings. Aix-en-Provence, France, May 14-18, 1973. Published by the International Atomic Energy Agency, Vienna, Austria, 1973.

*Blanchard, R.L. and J.B. Moore. 1970. ^{210}Pb and ^{210}Po in tissues of some Alaskan residents as related to consumption of caribou or reindeer meat. Health Physics 18:127-134.

Blaylock, B.G. and J.P. Witherspoon. 1978. Evaluation of radionuclides released from the light water reactor nuclear fuel cycle to the aquatic environment. In: Environmental Chemistry and Cycling Processes. D.C. Adriano and I.L. Brisbin, Jr. (eds.). Published by the Technical Information Center, U.S. Department of Energy.

Bloom, S.G. and G.E. Raines. 1971. Mathematical models for predicting the transport of radionuclides in a marine environment. BioScience 21(12):691-696.

Bondietti, E.A. and C.R. Olsen. 1982. Critical geochemical variables affecting radionuclide migration assessments. American Chemical Society, Abstracts of Papers 183:22.

Boone, F.W., Y.C. Ng and J.M. Palms. 1981. Terrestrial pathways of radionuclide particulates. Health Physics 41(5):735-747.

Bourke, P.J., M.H. Bradbury, G.V. Evans, F.T. Ewart, D.P. Hodgkinson, M. Ivanovich, D.V. Kinsey, J.B. Lewis, J.B. Morris and J. Rae. 1983. Nuclide migration and Mathematical Modelling. European Applied Research Reports, Nuclear Science Technology 5(2):145-174.

Breslin, A.J. and H. Glauberman. 1980. Investigation of radioactive dust dispersed from uranium tailings piles. In: Environmental Surveillance in the Vicinity of Nuclear Facilities. Proceedings of a Symposium sponsored by the Health Physics Society. W.C. Reinig (ed.), Charles C. Thomas, Publisher.

Brisbin, I.L., Jr., R.A. Geiger and M.H. Smith. 1973. Accumulation and redistribution of radiocaesium by migratory waterfowl inhabiting a reactor cooling reservoir. In: Environmental Behaviour of Radionuclides Released in the Nuclear Industry. Symposium Proceedings. Aix-en-Provence, France, May 14-18, 1973. Published by the International Atomic Energy Agency, Vienna, Austria, 1973.

Bruland, W., B. Franke and D. Teufel. 1979. Transfer of organically bound radionuclides through foodchains to man. Model-example with radiocobalt and vitamine B_{12}. In: Biological Implications of Radionuclides Released from Nuclear Industries. Proceedings of an International Symposium on Biological Implications of Radionuclides Released from Nuclear Industries Organized by the International Atomic Energy Agency. Vienna, 26-30 March 1979.

Bufatin, O.I., N.P. Parashchuko, N.D. Fomkina and R.M. Aleksakhin. 1984. Distribution of some radionuclides in the soil-irrigation water system (model experiment). Soviet Soil Science 15(4):5-61 (Translated from: Pochvovedeniye 8:133-136. 1982).

*Bunzl, K. and W. Kracke. 1984. Distribution of ^{210}Pb, ^{210}Po, stable lead and fallout ^{137}Cs in soil, plants and moorland sheep of a heath. The Science of the Total Environment 39:143-159.

Carnahan, C.L., C.W. Miller and J.S. Remer. 1984. Verification and Movement of Predictive Algorithms for Radionuclide Migration. Report by University of California, Lawrence Berkeley Laboratory. LBL-17133.

*Chadwick, R.C. and A.C. Chamberlain. 1970. Field loss of radionuclides from grass. Atmospheric Environment 4:51-56.

Chamberlain, A.C. 1970. Interception and retention of radioactive aerosols by vegetation. Atmospheric Environment 4:57-78.

*Chapman, T.S. and S. Hammons, Jr. 1963. Some observations concerning uranium content of ingesta and excreta of cattle. Health Physics 9:79-81.

Chen, B.C-J., J.R. Hull, M.G. Seitz, W.T. Sha, V.L. Shah and S.L. Soo. 1984. Mathematic Modeling and Evaluation of Radionuclide Transport Parameters from the ANL Laboratory analog program. Report prepared by Argonne National Laboratory. ANL-84-13.

Chomyn, B.A. and G.M. Ritcey. 1983. Uranium tailings lysimeters: A plan for predictive migration of radionuclides and contaminants within the environment. Journal of Metals 35(12)27 (Abstract).

Clayton, J.R., Jr., T.H. Sibley and W.R. Schell. 1981. Distribution Coefficients for Radionuclides in Aquatic Environments, Effects of Dissolved Organic Comounds on the Distribution Coefficients of ^{57}Co, ^{106}Ru, ^{137}Cs and ^{241}Am. Report prepared for the U.S. Nuclear Regulatory Commission NUREG/CR-1853. Volume 1.

*Clemente, G.F., A. Renzetti, G. Santori, and F. Breuer. 1980. Assessment of ^{210}Po exposure for the Italian population. In: Radiation Protection. A Systematic Approach to Safety. Proceedings of the 5th Congress of the International Radiation Protection Society, Jerusalem, March 1980. Volume 2, pp. 1091-1093.

Clemente, G.F., P. Belloni, S. DiPietro and G. Santori. 1979. Tritium and plutonium content of the Italian diet and transfer to man. In: Biological Implications of Radionuclides Released from Nuclear Industries. Proceedings of an International Symposium on Biological Implications of Radionuclides Released from Nuclear Industries Organized by the International Atomic Energy Agency. Vienna, 26-30 March 1979.

Comar, C.L. 1966. Radioactive materials in animals-entry and metabolism. In: Radioactivity and Human Diet. R.S. Russell (ed.), Pergamon Press, Toronto. Chapter 7, pp. 129-157.

Comar, C.L. and F.W. Lengemann. 1967. General principles of the distribution and movement of artificial fallout through the biosphere to man. In: Radioecological Concentration Processes. Proceedings of an International Symposium held in Stockholm 25-29 April, 1966. B. Aberg and F.P. Hungate (eds.), Pergamon Press, Toronto.

Cooper, E.L. and J.O. McHugh. 1983. Migration of radiocontaminants in a forested wetland on the Canadian shield: Nuclide speciation and arboreal uptake. The Science of the Total Environment 28:215-230.

*Coughtrey, P.J. and M.C. Thorne. 1983. Radionuclide Distribution and Transport in Terrestrial and Aquatic Ecosystems - A Critical Review of Data. Volume 1. General Principles. A.A. Balkema/Rotterdam.

Crick, M.J. and J.R. Simmonds. 1984. Models for the transfer of radionuclides in cattle for use in radiological assessments. The Science of the Total Environment 35:227-238.

Cuddihy, R.C., R.O. McClellan, L.D. Chapman, J.R. Wayland and V.L. Dugan. 1975. Simulation modelling of environmental transport and health consequences of radioactive effluents from nuclear power systems. In: Transuranium Nuclides in the Environment. Proceedings of the Symposium on Transuranium Nuclides in the Environment organized by the United States Energy Research and Development Administration and the International Atomic Energy Agency. Held in San Francisco, 17-20 November 1975.

Dahl, A.H., F.W. Whicker and G.C. Farris. 1966. Wild deer as a source of radionuclide intake by humans and as indicators of fallout hazards. Health Physics 12:1809 (Abstract).

Dahlman, R.C. et al. (22 authors). 1976. Nuclear materials transport. In: Environmental Sciences Division Annual Progress Report. Period Ending September 30, 1975. Publication No. 914. Oak Ridge National Laboratory ORNL-5193.

*Davé, N.K., T.P. Lim and N.R. Cloutier. 1985. Ra-226 concentrations in blueberries Vaccinium angustifolium Ait near an inactive uranium tailings site in Elliot Lake, Ontario, Canada. Enviromental Pollution (Series B) 10:301-314.

Davis, P.A., A. Reimer, S.K. Sakiyama and P.R. Slawson. 1986. Short-range atmospheric dispersion over a heterogenous surface. 1. Lateral dispersion. Atmospheric Environment 20(1):41-50.

*Dean, M.H. 1966. A survey of the uranium content of vegetation in Great Britain. Journal of Ecology 54:589-595.

Denham, D.H. 1979. Environmental radiological surveillance in perspective: relative importance of environmental media as a function of effluent pathway and radionuclides. Health Physics 36:273-281.

*DiGregorio, D., T. Kitchings and P. van Voris. 1978. Radionuclide transfer in terrestrial animals. Health Physics 34:3-31.

*Dory, A.B. 1981. Environmental Impact of Uranium Mining and Milling - A Canadian Experience. Atomic Energy Control Board, Ottawa, Canada.

*D'Souza, T.J. and K.B. Mistry. 1970. Comparative uptake of thorium-230, radium-226, lead-210 and polonium-210 by plants. Radiation Botany 10:293-295.

*Dusauskene-Duz, R.F. and G.G. Polikarpov. 1978. Extraction and accumulation of ^{210}Pb by aquatic organisms in lakes. Hydrobiological Journal (USSR) 14(3):62-67.

Edison, A.F. 1984. Biological Characterization of Radiation Exposure and Dose Estimates for Inhaled Uranium Milling Effluents. Report to the U.S. Nuclear Regulatory Commission by Lovelace Biomedical and Environmental Research Institute.

*Eisenbud, M. and E.P. France. 1984. Studies of transport pathways of Th, U, REE's, Ra-228 and Ra-226 from soil to farm animal - Progress Report. Report to the U.S. Department of Energy by New York University DOE/ER/60134-1.

Ekman, L. 1967. Mechanisms of uptake and accumulation of radionuclides in terrestrial animals. _In_: Radioecological Concentration Processes. Proceedings of an International Symposium held in Stockholm 25-29 April, 1966. B. Abert and F.P. Hungate (eds.), Pergamon Press, Toronto.

*Elias, R., Y. Hirao, and C.C. Patterson. 1978. The deposition of lead aerosols on plant surfaces in a remote subalpine ecosystems. In: Environmental Chemistry and Cycling Processes. Proceedings of a symposium held at Augusta, Georgia April 28-May 2. D.C. Adriano and I.L. Brisbin, Jr. (eds.).

Engelmann, E. 1961. Estimate of the dietary intake of radium-226 for New York City infants. In: Health and Safety Laboratory Fallout Program. Quarterly Summary Report. E.P. Hardy, Jr., J. Rivera and R. Frankel (eds.). U.S. Atomic Energy Commission, New York Operations Office.

Ewart, F.T., J.B. Lewis and J.B. Morris. 1983. Migration of Radionuclides Through the Geosphere: An Integral Migration Experiment. European Applied Research Reports. Nuclear Science Technology 5(2):253-266.

*Faust, R.A. and E.A. Bondietti. 1976. Biogeochemical Aspects of the Behaviour of Uranium and Thorium in the Environment. Report by Oak Ridge National Laboratory. ORNL/EIS-99. (Bibliography of 383 references mostly dealing with geochemical movement in soils and aquatic systems. Accumulations in plants and animals and transfer coefficients not well documented).

Fisenne, I.M. 1968. Distribution of ^{210}Pb and ^{226}Ra in soil. In: Proceedings of the 13th Annual Bioassay and Analytical Chemistry Meeting held at Lawrence Radiation Laboratory. October 1967. A de G. Low-Beer (ed.). UCRL-18140, CONF-671048.

Foglia, M. 1983. Radionuclide migration in transport paths bounded by the environment. Transactions of the American Nuclear Society 44:116-117.

Fowler, E.B., W.L. Polzer and E.H. Essington. 1983. Influence of Soil Biopopulation on Migration of Waste Radionuclides. Report by the Los Alamos National Laboratory.

Fowler, S.W. 1985. Heavy metal and radioactive transfer and transport by marine organisms. Symposium Biologica Hungarica 29, pp. 191-206.

Frissel, M.J. and R. Pennders. 1982. Models for the migration of ^{90}Sr, ^{137}Cs, ^{239,240}Pu, and ^{241}Am in the top layer of soils. In: Environmental Migration of Long-Lived Radionuclides. Proceedings of an International Symposium on Migration in the Terrestrial Environment of Long-Lived Radionuclides from the Nuclear Fuel Cycle. Knoxville, Tennessee, USA, 27-31 July 1981. Published by the International Atomic Energy Agency.

Fukai, R. and C.N. Murray. 1973. Environmental behaviour of radiocobalt and radiosilver released from nuclear power stations into aquatic systems. In: Environmental Behaviour of Radionuclides Released in the Nuclear Industry. Symposium Proceedings. Aix-en-Provence, France, May 14-18, 1973. Published by the International Atomic Energy Agency, Vienna, Austria, 1973.

*Gallegos, A.F. and W.J. Wenzel. 1984. HUMTRN: Documentation and Verification for an ICRP-based Age- and Sex-specific Human Simulation Model for Radionuclide Dose Assessment. Report prepared by the Los Alamos National Laboratory, LA 9994-MS.

*Gallegos, A.F., W.J. Smith, II and L.J. Johnson. 1978. LASL models for environmental transport of radionuclides in forests. Presented at the University of Pittsburgh Modeling and Simulation Conference, April 27-28, 1978.

*Gallegos, A.F., B.J. Garcia and C.M. Sutton. 1980. Documentation of TRU Biological Transport Model (BIOTRAN). Report prepared by the University of California Los Alamos Scientific Laboratory, New Mexico.

*Garner, R.J. 1971. Transfer of radioactive materials from the terrestrial environment to animals and man. CRC Critical Reviews in Environmental Control 2(3):337-385. (Note: This article identical to book published by CRC Press under the same title.)

*Garten, C.T., Jr. 1978. A review of parameter values used to assess the transport of plutonium, uranium, and thorium in terrestrial food chains. Environmental Research 17:437-452.

Garten, C.T., Jr. 1981. Comparative uptake of actinides by plants and rats from the shoreline of a radioactive pond. Journal of Environmental Quality 10(4):487-491.

*Garten, C.T., Jr., E.A. Bondietti, and R.L. Walker. 1981. Comparative uptake of uranium, thorium, and plutonium by biota inhabiting a contaminated Tennessee floodplain. Journal of Environmental Quality. 10(2):207-210.

*Garten, C.T., Jr., J.R. Trabalka, and M.A. Bogle. 1982. Comparative food chain behaviour and distribution of actinide elements in and around a contaminated fresh-water pond. In: Environmental Migration of Long-Lived Radionuclides from the Nuclear Fuel Cycle. Knoxville, Tennessee, U.S.A., 27-31, July 1981. Published by the International Atomic Energy Agency.

Gustafson, P.F. 1967. Comments on radionuclides in aquatic ecosystems. In: Radioecological Concentration Processes. Proceedings of an International Symposium held in Stockholm 25-29 April, 1966. B. Aberg and F.P. Hungate (eds.) Pergamon Press, Toronto.

Guthrie, J.E. 1964. Radioactivity in Winnipeg River Water. Atomic Energy of Canada Limited AECL-1874.

Hadermann, J. 1982. The influence of speciation on the geospheric migration of radionuclides. Nuclear Technology 56:102-105.

Hadermann, J. and M. Schweingruber. 1982. Influence of speciation on the geospheric migration of radionuclides. In: Environmental Migration of Long-Lived Radionuclides. Proceedings of an International Symposium on Migration in the Terrestrial Environment of Long-Lived Radionuclides from the Nuclear Fuel Cycle. Knoxville, Tennessee, USA, 27-31 July 1981. Published by the International Atomic Energy Agency.

*Hallden, N.A. and I.M. Fisenne. 1961. Radium-226 in the diet in three U.S. Cities. In: Health and Safety Laboratory Fallout Program. Quarterly Summary Report. E.P. Hardy, Jr., J. Rivera, R. Frankel (eds.), U.S. Atomic Energy Commission. New York Operations Office. HASL-113.

Hamilton, E.I. 1967. Some problems concerning lead in the natural environment. In: Radioecological Concentration Processes. Proceedings of an International Symposium held in Stockholm 25-29 April 1966. B. Aberg and F.P. Hungate (eds.), Pergamon Press, Toronto.

Hamilton, E.I. 1970a. The concentration of uranium in air from contrasted natural environments. Health Physics 19:511-520.

Hamilton, E.I. 1970b. The concentration of uranium in man and his diet. Health Physics 19:117. (Abstract).

Hanson, W.C. 1967. Radioecological concentration processes characterizing arctic ecosystems. In: Radioecological Concentration Processes. Proceedings of an International Symposium held in Stockholm 25-29 April 1966. B. Aberg and F.P. Hungate (eds.), Pergamon Press, Toronto.

Hanson, W.C., D.G. Watson and R.W. Perkins. 1967. Concentration and retention of fallout radionuclides in Alaskan arctic ecosystem. In: Radioecological Concentration Processes. Proceedings of an International Symposium held in stockholm 25-29 April, 1966. B. Aberg and F.P. Hungate (eds.) Pergamon Press, Toronto.

Hart, D.R., J. Fitchko, D.L. Lush, C.R. Phillips and F.C. Lendrum. 1985. Procedures for Evaluation of Data in Environmental Databases, with Particular Reference to Uranium Tailings. A report prepared for The National Uranium Tailings Program. Canada Centre for Mineral and Energy Technology, Energy, Mines and Resources Canada.

Harvey, R.S. 1964. Uptake of radionuclides by fresh water algae and fish. Health Physics 10:243-247.

Hasler, A.D. and G.E. Likens. 1961. Biological and physical transport of radionuclides in stratified lakes. In: Radioecology, Proceedings of the First National Symposium on Radioecology held at Colorado State University, Fort Collins, Colorado, September 10-15, 1961. V. Schultz and A.W. Klement, Jr. (eds.).

*Haulik, B. 1967. Cumulation of radioactive substances by organisms of natural biocenosis of surface waters and its significance for determination of radioactive load. Journal of Hygiene, Epidemiology, Microbiology and Immunology 11:229-245.

*Havlik, B. 1970. Radium-226 Content of Water and Plankton from the Chalk River Area. Atomic Energy of Canada Limited. Report AECL-3687.

*Havlik, B. 1971. Radium in aquatic food chains: Radium uptake by frshwater algae. Radiation Research 46:490-505.

*Havlik, B. and E. Robertson. 1971. Radium uptake by freshwater algae. In: Proceedings of the Third National Symposium on Radioecology, May 10-12, 1971, Oak Ridge, Tennessee. Volume 1, pp. 372-380.

Haywood, S.M., J.R. Simmonds and G.S. Linsley. 1980. The Development of Models for the Transfer of ^{137}Cs and ^{90}Sr in the Pasture-Cow-Milk Pathway Using Fallout Data. National Radiation Protection Board. Didcot, Harwell, Oxon OX11 ORQ. Report No. NRPB-R110.

Heine, K. and A. Wiechen. 1979. Studies on the transfer factors of Sr-90 (strontium isotope) and further fall-out radionuclides in the food chain soil-plant-milk in the surroundings of Gorlaben. Kieler Milchwirtschaftliche Forschungsherichte 31(4):283-295.

*Hesslein, R.H. and E. Slavicek. 1984. Geochemical pathways and biological uptake of radium in small Canadian shield lakes. Canadian Journal of Fisheries and Aquatic Sciences 41:459-468.

Higashi, K. and T.H. Pigford. 1980. Analytical models for migration of radionuclides in geologic sorbing media. Journal of Nuclear Sciences and Technology 17(9:700-709.

*Hill, C.R. 1960. Lead-210 and polonium-210 in grass. Nature (London) 187(4733):211-212.

*Hill, C.R. 1967. Routes of uptake of ^{210}Po into human tissues. In: Radioecological Concentration Processes. Proceedings of an International Symposium held in Stockholm 25-29 April 1966. B. Aberg and F.P. Hungate (eds.), Pergamon Press, Toronto.

*Hill, C.R. and Z.S. Jaworowski. 1961. Lead-210 in some human and animal tissues. Nature 190(4773):353-354.

Hinrichsen, K. 1986. Comparison of four analytical dispersion models for near-surface releases above a grass surface. Atmospheric Environment 20(1):29-40.

Hoffman, F.O. 1977. A reassessment of the deposition velocity in the prediction of the environmental transport of radionuclides from air to milk. Health Physics 32:437-441.

*Hoffman, F.O. and C.F. Baes, III. 1979. A Statistical Analysis of Selected Parameters for Predicting Food Chain Transport and Internal Dose of Radionuclides. Report prepared by Oak Ridge National Laboratory for the U.S. Nuclear Regulatory Commission NUREG/CR-1004.

Hoffman, F.O., C.W. Miller, D.L. Shaeffer and C.T. Garten, Jr. 1977. Computer codes for the assessment of radionuclides released to the environment. Nuclear Safety 18(3):343-354.

Hoffman, F.O., U. Bergstrom, C. Gyllander, and A.B. Wilkens. 1984. Comparison of predictions from internationally recognized assessment models for the transfer of selected radionuclides through terrestrial food chains. Nuclear Safety 25(4):533-546.

Hoffman, F.O., D.L. Shaeffer, C.F. Baes III, C.A. Little, C.W. Miller, D.E. Dunning, Jr., E.M. Rupp, R.W. Shar. 1978. An evaluation of uncertainties in radioecological models. In: Proceedings of the 12th Annual Conference on the German-Swiss Health Physics Society, Norderney, Federal Republic of Germany.

Hollingsworth, D.F. and E.A. Hobson. 1966. Composition of Human Diet. In: Radioactivity and Human Diet. R.S. Russell (ed.) Pergamon Press, Toronto, Chapter 4 pp.65-83.

Holm, E and R.B.R. Persson. 1975. Transfer of fall-out plutonium in the food-chain lichen-reindeer-man. In: Transuranium Nuclides in the Environment. Proceedings of the Symposium on Transuranium Nuclides in the Environment organized by the United States Energy Research and Development Administration and the International Atomic Energy Agency. Held in San Francisco, 17-20 November 1975.

*Holtzman, R.B. 1966. Natural levels of lead-210, polonium-210 and radium-226 in humans and biota of the arctic. Nature (London) 210:1094-1097.

Homma, Y., M. Sumiya, Y. Muramatus and Y. Ohmomo. 1983. Specific activity approach on the estimation of radionuclide transfer from soil to plant. Journal of Radiation Research 24(1):90 (Abstract).

*Hubel, K., H. Herrmann and M. Ruf. 1979. Long-term accumulation factors for fish and sediments in the Bavarian Danube area. In: Biological Implications of Radionuclides Released from Nuclear Industries. Proceedings of an International Symposium on Biological Implications of Radionuclides Released from Nuclear Industries Organized by the International Atomic Energy Agency. Vienna, 26-30 March 1979.

Hunt, G.J. and J.G. Shepherd. 1980. The identification of critical groups. In: Radiation Protection. A Systematic Approach to Safety. Proceedings of the 5th Congress of the International Radiation Protection Society, Jerusalem, March 1980. Volume 1, pp. 141-144.

Hursh, J.B. 1953. The Radium Content of Public Water Supplies. The University of Rochester Atomic Energy Project. Contract W-7401-ENG-49 UR-257.

*Hursh, J.B. 1957. Natural occurrence of radium in man and in waters and in food. British Journal of Radiology Supplement, pp. 45-53.

*Ibrahim, S.A., S.L. Flot, and F.W. Whicker. 1982. Concentrations and observed behaviour of ^{226}Ra and ^{210}Po around uranium mill tailings. In: Management of Wastes from Uranium Mining and Milling. Proceedings of an International Symposium of Management of Wastes from Uranium Mining and Milling. Albuquerque, New Mexico, 10-14 May 1982. Published by the International Atomic Energy Agency, Vienna.

*IEC Beak Consultants Ltd. 1983. An Approach To the Calculation of Dose Commitment Arising from Different Methods for the Long-Term Management of Uranium Mill Tailings Through Aquatic Pathways. Technical Appendix. A report prepared for the Atomic Energy Control Board.

Isherwood, D. 1978. Geochemistry and radionuclide migration. Presented at the Waste Management and Fuel Cycles Symposium, Tucson, Arizona, March 6-8, 1978.

Janke, D.H. and W.J. Arthur. 1985. Radionuclide transport by cottontail rabbits at a radioactive waste disposal area. Northwest Science 59(3):221-229.

Jaworowski, Z. 1977. Migracje Radionuklidow I Metali Ciezkich w Grodowisku (Migration of radionuclides and heavy metals in the environment). Kosmos, Seria A, Biologia 26:25-39.

Jinks, S.M. and M. Eisenbud. 1972. Concentration factors in the Aquatic Environment. Radiation Data and Reports 13:243-247.

John, R.D. 1985. Fish Study for the National Uranium Tailings Program (NUTP). Research Report NUTP-85-4 (TR).

Johns, T.F. 1979. Environmental Pathways of Radioactivity to Man. Atomic Energy Establishment - Winfrith, Dorchester, Dorset, England. AEE-R1288, December, 1979.

*Johnson, J.E. 1978. Pathways of radionuclides released from tailings piles. In: Symposium on Uranium Mill Tailings Managment, Ft. Collins, CO. Nov. 20-21, 1978. Colardo State University.

Johnson, J.E., T.R. Tyler and G.M. Ward. 1969. Transfer of fallout cesium-137 from feed to meat of cattle. Journal of Animal Science 29:695-699.

*Justyn, J. and S. Lusk. 1976. Evaluation of natural radionuclide contamination of fishes in streams affected by uranium ore mining and milling. Zoologické Listy 25(3):265-274.

*Justyn, J. and Z. Stanek. 1974. Accumulation of natural radionuclides in the bottom sediments and by aquatic organisms of streams. Internationale Revue der Gesamten Hydrobiologie 59(5):593-609.

Kahn, B., J. Golden, A. Goldin, and P. Magno. 1979. Definition of critical pathways and radionuclides for population radiation exposure at nuclear power stations. Health Physics 37(6):836. (Abstract).

Kaindl, K. 1951. Behaviour of Radium in Plants and Soils (Verhalten von Radium in Pflanze and Boden). Die Bodenkultur 5(4):425436.

*Kalin, M. and H.D. Sharma. 1981. Radium-226 and lead-210 uptake in Typha latifolia from inactive uranium mill tailings in Canada. In: Environmental Migration of Long-Lived Radionuclides. Proceedings of an International Symposium on Migration in the Terrestrial Environment of Long-Lived Radionuclides from the Nuclear Fuel Cycle. Knoxville, Tennessee, USA, 27-31 July 1981. Published by the International Atomic Energy Agency.

*Kalin, M. 1982. Environmental Conditions of Two Abandoned Uranium Mill Tailings Sites in Northern Saskatchewan. Report prepared for Saskatchewan Environment.

*Kanak, K.A. and C.W. Miller. 1980. Evaluation of Models Used for the Assessment of Radionuclide Releases to the Environment. Report by Oak Ridge National Laboratory. ORNL-5573.

*Kauranen, P. and J.K. Miettinen. 1967. ^{210}Po and ^{210}Pb in environmental samples in Finland. In: Radioecological Concentration Processes. Proceedings of an International Symposium held in Stockholm 25-29 April 1966. B. Aberg and F.P. Hungate (eds.), Pergamon Press, Toronto.

*Kaye, S.V., F.O. Hoffman, L.M. McDowell-Boyer and C.F. Baes. 1981. Development and Application of Terrestrial Food Chain Models & Assess Health Risks to Man and Releases of Pollutants to the Environment. Oak Ridge National Laboratory Report.

*Kennedy, W.E., Jr., L.L. Cadwell and D.H. McKenzie. 1985. Biotic transport of radionuclides from a low-level radioactive waste site. Health Physics 49(1):11-24.

*Kiefer, J., A. Wicke, F. Glaum and J. Porstendörfer. 1980. ^{226}Ra- and ^{222}Rn-content of drinking water. In: Radiation Protection. A Systematic Approach to Safety. Proceedings of the 5th Congress of the International Radiation Protection Society, Jerusalem, March 1980.

King, C.M. and R.W. Root, Jr. 1982. Radionuclide migration model for buried waste at the Savannah River plant. American Nuclear Society Waste Management Symposium. Tucson, Arizona, March 8-11.

*Kirchmann, R., R. Boulenger and A. Lafontaine. 1966. Uptake of ^{226}Ra by crop plants. Health Physics 12:1805-1806 (Abstract).

Kirchner, T.B. and F.W. Whicker. 1984. Validation of PATHWAY: A simulation model of the transport of radionuclides through agroecosystems. Ecologial Modelling 22:21-44.

*Kirchner, T.B., F.W. Whicker and M.D. Otis. 1982. PATHWAY: A simulation model of radionuclide transport through agricultural food chains. In: Third International Conference on State-of-the-Art Ecological Modeling. Colorado State University May 24-27. CONF 820596-3.

*Klement, A.W., Jr. 1965. Natural radionuclides in foods and food source materials. In: Radioactive Fallout, Soils, Plants, Foods, Man. E.B. Fowler (ed.), Elsevier Publishing Company, New York.

*Knight, M.J. 1983. Uptake by Plants of Radionuclides from FUSRAP Waste Materials. Report by Argonne National Laboratory. ANL/EIS-19.

Kocher, D.C. 1984. External dose-rate conversion factors. In: Models and Parameters for Environmental Radiological Assessments. C.W. Miller (ed.). Prepared for the Office of Nuclear Energy, U.S. Department of Energy. Published by the Technical Information Center, U.S. Department of Commerce.

Kocher, D.C. and G.G. Killough. 1984. A review of global environmental transport models for ^{3}H, ^{14}C, ^{85}Kr, and ^{129}I. In: Radioactive Waste Management. Proceedings of an International Conference on Radioactive Waste Management held by the International Atomic Energy Agency, Seattle, 16-20 May 1983. Published by the International Atomic Energy Agency, 1984.

*Kornberg, H.A. and J.J. Davis. 1966. Food chains in fresh water. In: Radioactivity and Human Diet. R.S. Russell (ed.). Pergamon Press, Toronto. Chapter 18, pp. 385-418.

*Kovalsky, V.V., I.E. Vorotnitskaya and V.S. Lekarev. 1967. Biogeochemical food chains of uranium in aquatic and terraneous organisms. In: Radioecological Concentration Processes. Proceedings of an International Symposium held in Stockholm 25-29 April, 1966. B. Aberg and F.P. Hungate (eds.) Pergamon Press, Toronto.

Krieger, H.L., B. Kahn and S. Cummings. 1967. Deposition and uptake of ^{90}Sr and ^{137}Cs in an established pasture. In: Radioecological Concentration Processes. Proceedings of an International Symposium held in Stockholm 25-29 April, 1966. B. Aberg and F.P. Hungate (eds.) Pergamon Press, Toronto.

Krivolutskii, D.A., A.D. Pokarzhevskii, A.I. Taskaev, Z.A. Milha'tsora, T.M. Semyashkina and I.I. Shuktomova. 1981. Migration of natural radionuclides (uranium, radium, thorium) through populations of saprophages. Akademiia Nauk SSSR. Doklady, Biological Sciences 260(1/6):449-451.

Krivolutsky, D.A., G.A. Korganova and F.A. Tikhomirov. 1983. Some radioecological problems of terrestrial and soil animals. In: Proceedings of the VIII Intl. Colloquium of Soil Zoology. Louvain-la-Neuve (Belgium). August 30 - September 2, 1982. Edited by Ph. Lebrun, H.M. André, A. de Medts, C. Grégoire-wibo and G. Wauthy. Imprimeur Dieu-Brichart, Ottignies-Louvain-la-Neuve (1983).

Krumholz, L.A. 1967. Accumulation of radioactive fallout materials in the biota of Doe Run, Meade County, Kentucky, 1959-63. In: Radioecology Concentration Processes. Proceedings of an International Symposium held in Stockholm 25-29 April, 1966. B. Aberg and F.P. Hungate (eds.) Pergamon Press, Toronto.

Larsson, A., K. Andersson, B. Grundfeit and J. Hadermann. 1984. Mathematical models for nuclide transport in geologic media - An international intercomparison (INTRACOIN). In: Radioactive Waste Management. Proceedings of an International Conference on Radioactive Waste Management held by the International Atomic Energy Agency, Seattle, 16-20 May 1983. Published by the International Atomic Energy Agency, 1984.

Lassey, K.R. 1980. The usage of transfer-coefficients to describe radionuclide transport from a cows diet to its milk. Health Physics 39(2):321-325.

Lee, D.W., R.H. Ketelle, F.G. Pin and G.S. Hill. 1984. Environmental pathways analysis for evaluation of a low-level waste disposal site. In: Radioactive Waste Management. Proceedings of an International Conference on Radioactive Waste Management held by the International Atomic Energy Agency, Seattle, 16-20 May 1983. Published by the International Atomic Energy Agency, 1984.

Lever, D.A. and J. Rae. NAMTAR: A new computer program for the transport of radionuclides in groundwater flow. In: Environmental Migration of Long-Lived Radionuclides. Proceedings of an International Symposium on Migration in the Terrestrial Environment of Long-Lived Radionuclides from the Nuclear Fuel Cycle. Knoxville, Tennessee, USA, 27-31 July 1981. Published by the International Atomic Energy Agency.

Likens, G.E. and P.L. Johnson. 1967. Measurements of background radiation in aquatic habitats in Alaska. In: Proceedings of the 2nd National Symposium on Radioecology CONF-670503. D.J. Nelson and F.C. Evans (eds.).

*Linsley, G.S. and J.R. Simmonds. 1982. An analysis of long-term exposure pathways in the terrestrial environment following the release of radioactive materials to atmosphere. In: Environmental Migration of Long-Lived Radionuclides. Proceedings of an International Symposium on Migration in the Terrestrial Environment of Long-Lived Radionuclides from the Nuclear Fuel Cycle. Knoxville, Tennessee, U.S.A., 27-31, July 1981. Published by the International Atomic Energy Agency.

Linsley, G.S., S.M. Haywood and J. Dionian. 1982. Use of fall-out data in the development of models for the transfer of nuclides in the terrestrial and freshwater systems. In: Environmental Migration of Long-Lived Radionuclides. Proceedings of an International Symposium on Migration in the Terrestrial Environment of Long-Lived Radionuclides from the Nuclear Fuel Cycle. Knoxville, Tennessee, USA, 27-31 July 1981. Published by the International Atomic Energy Agency.

Little, C.A. 1984. Surface water transport. In: Models and Parameters for Environmental Radiological Assessments. C.W. Miller (ed.). Prepared for Office of Nuclear Energy, U.S. Department of Energy. Published by the Technical Information Center, U.S. Department of Commerce.

Longhurst,W.M., M. Goldman, and R.J.D. Rosa. 1967. Comparison of the environmental and biological factors affecting the accumulation of ^{90}Sr and ^{137}Cs in deer and sheep. In: Radioecological Concentration Processes. Proceedings of an International Symposium held in Stockholm 25-29 April, 1966. B. Aberg and F.P. Hungate (eds.) Pergamon Press, Toronto.

*Lush, D.L., W.J. Snodgrass and P. McKee. 1982. Aquatic pathway variables affecting the estimation of dose commitment from uranium mill tailings. In: Management of Wastes from Uranium Mining and Milling. Proceedings of an International Symposium on Management of Wastes from Uranium Mining and Milling. Albuquerque, New Mexico, 10-14 May 1982. Published by the International Atomic Energy Agency, Vienna.

Magi, A. and B. Lindell. 1967. ^{222}Rn in milk. In: Radioecological Concentration Processes. Proceedings of an International Symposium held in Stockholm 25-29 April 1966. B. Aberg and F.P. Hungate (eds.), Pergamon Press, Toronto.

*Magno, P.J., P.R. Groulx and J.C. Apidianakis. 1970. Lead-210 in air and total diets in the United States during 1966. Health Physics 18:383-388.

Mahmoud, K.A., Y.A. Yousef, M.M. Ishak, W.E.Y. Abdel-Malik, S.R. Khalil, A. Shafik and R.M.K. El-Shinawy. 1973. Transfer mechanism and concentrating processes of certain radionuclides in the aquatic ecology of the Ismailia Canal. In: Environmental Behaviour of Radionuclides Released in the Nuclear Industry. Symposium Proceedings. Aix-en-Provence, France, May 14-18, 1973. Published by the International Atomic Energy Agency, Vienna, Austria, 1973.

*Mahon, D.C. 1982. Uptake and translocaton of naturally occurring radionuclides of the uranium series. Bulletin of Environmental Contamination and Toxicology 29:697-703.

*Mahon, D.C. and R.W. Mathewes. 1983. Seasonal variation in the accumulation of radionuclides of the uranium series by yellow pond-lily (Nuphar lutea). Bulletin of Environmental Contamination and Toxicology 30:575-581.

Mansfeld, A. 1981. Research into the Behaviour and Transport of Radionuclides in Waters. Methods of Testing Sorption Properties of Materials Present in Aquatic Environment and Evaluation of Results. Report prepared for the International Atomic Energy Agency.

*Marchyulenene, P.D., R.F. Dushauskene-Duzh, E.B. Moteyunene, V.B. Nyanishkene, G.G. Polikarpov and L.N. Vorab'ev. 1978. Accumulation of ^{210}Pb in freshwater plants. Hydrobiological Journal 14(6):73-71.

Marey, A.N. and M.M. Saurov. 1967. Material for assessment of the role played by food chains in ^{90}Sr migration from freshwater reservoirs into the diet of man. In: Radioecological Concentration Processes. Proceedings of an International Symposium held in Stockholm 25-29 April, 1966. B. Abert and F.P. Hungate (eds.), Pergamon Press, Toronto.

Marietta, M.G., J.R. Wayland, G.E. Runkle, D.W. Jackson, J.H. Baker and A. Kwok. 1981. Aquatic Foodweb Radionuclide Migration Model. Report by Sandia National Laboratory, SAND-80-1047, NUREG/CR-1453.

Marple, M.L. 1980. Radium-226 in Vegetation and Substrates of Inactive Uranium Mill Sites. Report prepared by the Los Alamos Scientific Laboratory.

Marple, M.L. and L.D. Potter. 1982. Uptake of radium-226 by plants at inactive uranium mill sites in the southwestern USA. In: Environmental Migration of Long-Lived Radionuclides. Proceedings of an International Symposium on Migration in the Terrestrial Environment of Long-Lived Radionuclides from the Nuclear Fuel Cycle. Knoxville, Tennessee, USA, 27-31 July 1981. Published by the International Atomic Energy Agency.

*Martin, S.S., W.T. Helm, and W.F. Sigler. 1967. Accumulation of ^{226}Ra in two aquatic ecosystems. In: Proceedings of the Second National Symposium on Radioecology. D.J. Nelson and F.C. Evans (eds.) CONF 670503.

McDowell-Boyer, L.M. and C.F. Baes, III. 1984. Terrestrial food-chain transport. In: Models and Parameters for Environmental Radiological Assessments. C.W. Miller (ed.). Prepared for Office of Nuclear Energy, U.S. Department of Energy. Published by the Technical Information Center, U.S. Department of Commerce.

*McDowell-Boyer, L.M., A.P. Watson and C.C. Travis. 1979. Foodchain transport of ^{210}Pb resulting from uranium milling activities. In: Biological Implications of Radionuclides Released from Nuclear Industries. Proceedings of an International Symposium on Biological Implications of Radionuclides Released from Nuclear Industries Organized by the International Atomic Energy Agency. Vienna, 26-30 March 1979.

McKenzie, D.H., L.L. Cadwell, L.E. Eberhart, W.E. Kennedy, Jr., R.A. Peloquin and M.A. Simmons. 1984. Relevance of Biotic Pathways to the Long-term Regulation of Nuclear Waste Disposal. Report for the U.S. Nuclear Regulatory Commission by Battelle Pacific Northwest Laboratories. NUREG/CR-2675.

*Menzel, R.G. 1965. Soil-plant relationships of radioactive elements. Health Physics 11:1325-1332.

Mernagh, J.R., P.J. Dinner, L.R. Olden and R.G. Tulk. 1982. Implications of pathway analysis of deminimus concentrations of radioactive waste. In: Proceedings of the American Nuclear Society Topical Meeting on the Treatment and Handling of Radioactive Wastes, pp. 615-619.

*Michelson, I. 1961. Radium-226 in the total diet. Health Physics 5:229-230.

*Michelson, I., J.C. Thompson, Jr., B.W. Hess and C.L. Comar. 1962. Radioactivity in total diet. Journal of Nutrition 78:371-383.

Miettinen, J.K. 1967. Concentration of ^{137}Cs and ^{55}Fe through food chains in arctic and subarctic regions. In: Radioecological Concentration Processes. Proceedings of an International Symposium held in Stockholm 25-29 April, 1966. B. Aberg and F.P. Hungate (eds.) Pergamon Press, Toronto.

Miettinen, K. 1979. Radioactive Foodchains in the Subarctic Environment. Report for the U.S. Department of Energy.

Miller, C.W. 1979. Validation of a model to predict aerosol interception by vegetation. In: Biological Implications of Radionuclides Released from Nuclear Industries. Proceedings of an International Symposium on Biological Implications of Radionuclides Released from Nuclear Industries Organized by the International Atomic Energy Agency. Vienna, 26-30 March 1979.

Miller, C.W. 1984. Example calculations. In: Models and Parameters for Environmental Radiological Assessments. C.W. Miller (ed.). Prepared for the Office of Nuclear Energy, U.S. Department of Energy. Published by the Technical Information Center, U.S. Department of Commerce.

Miller, C.W. and F.O. Hoffman. 1982. An analysis of reported values of the environmental half-time for radionuclides deposited on the surfaces of vegetation. In: Environmental Migration of Long-Lived Radionuclides. Proceedings of an International Symposium on Migration in the Terrestrial Environment of Long-Lived Radionuclides from the Nuclear Fuel Cycle. Knoxville, Tennessee, U.S.A., 27-31, July 1981. Published by the International Atomic Energy Agency.

*Miller, C.W., D.E. Dunning, Jr., E.L. Etnier, F.O. Hoffman, C.A. Little, H.R. Meyer, D.L. Shaeffer and J.E. Till. 1979. The Evaluation of Selected Predictive Models and Parameters for the Environmental Transport and Dosimetry of Radionuclides. Oak Ridge National Laboratory Report ORNL/TM-6663.

*Milosevic, Z., E. Horsic, R. Kljajic and A. Bauman. 1980. Distribution of uranium, ^{226}Ra, ^{210}Pb and ^{210}Po in the ecological cycle in the mountain regions of central Yugoslavia. In: Radiation Protection. A Systematic Approach to Safety. Proceedings of the 5th Congress of the International Radiation Protection Society, Jerusalem, March 1980.

Mitrovic, R.R. 1985. A study of K-40 and Cs-137 radionuclide migration during intensive pig breeding the Podrinje-Kolubara region of Serbia. Acta Berinaria (Beograd) 35(1-2):87-104.

Momeni, M.H. 1981. Environmental Aspects: Atmospheric-Aquatic-Terrestrial Dispersion of Radionuclides. Presented at the Symposium on Environmental Impact of Uranium Mining and Milling. Detroit, Michigan.

Murphy, B.D. 1982. RETADD II: Modeling long-range atmospheric transport of radionuclides. Transactions of the American Nuclear Society 41:57-58.

*Muth, H., B. Rajewsky, H.-J. Hatnke and K. Aurand. 1960. The normal radium content and the Ra^{226}/Ca ratio of various foods, drinking water and different organs and tissues of the human body. Health Physics 2:239-245.

Myttenaere, C., A. Avogadro and C.N. Murray. 1984. Environmental dispersion of long-lived radionuclides in the geosphere and biosphere. In: Radioactive Waste Management. Proceedings of an International Conference on Radioactive Waste Management held by the International Atomic Energy Agency, Seattle, 16-20 May 1983. Published by the International Atomic Energy Agency, 1984.

Nelson, C. and R. Sullivan. 1984. An integrated methodology for assessing the environmental impact of airborne radionuclides. Part II: Transport of atmospheric releases and application of unit exposure data to calculate individual and population risk. Health Physics 47(1):199 (Abstract).

Nelson, D.J. 1967. The prediction of ^{90}Sr uptake in fish using data on specific activities and biological half lives. In: Radioecological Concentration Processes. Proceedings of an International Symposium held in Stockholm 25-29 April 1966. B. Aberg and F.P. Hungate (eds.), Pergamon Press, Toronto.

*Nelson, N.S. and J.H. Rust. 1967. Distribution of and discrimination against naturally occurring ^{226}Ra in swine. In: Radioecological Concentration Processes. Proceedings of an International Symposium held in Stockholm 25-29 April, 1966. B. Aberg and F.P. Hungate (eds.) Pergamon Press, Toronto.

Neretnieks, I. 1982. Prediction of radionuclide migration in the geosphere: Is the porous-flow model adequate? In: Environmental Migration of Long-Lived Radionuclides. Proceedings of an International Symposium on Migration in the Terrestrial Environment of Long-Lived Radionuclides from the Nuclear Fuel Cycle. Knoxville, Tennessee, USA, 27-31 July 1981. Published by the International Atomic Energy Agency.

Nevstrueva, M.A., P.V. Ramzaev, A.A. Moiseer, M.S. Ibatullin and L.A. Teplykh. The nature of ^{137}Cs and ^{90}Sr transport over the lichen-reindeer-man food chain. In: Radioecological Concentration Processes. Proceedings of an International Symposium held in Stockholm 25-29 April, 1966. B. Abert and F.P. Hungate (eds.), Pergamon Press, Toronto.

Ng, Y.C. 1982. A review of transfer-factors for assessing the dose from radionuclides in agricultural products. Nuclear Safety 23(1):57-71.

Ng, Y.C., C.S. Colsher and S.E. Thompson. 1977. Transfer coefficients for the prediction of dose to man via the forage-cow-milk pathway from radionuclides released to the biosphere. Lawrence Livermore Laboratory Report UCRL-51939.

*Ng, Y.C., C.S. Colsher and S.E. Thompson. 1978. Transfer coefficients for terrestrial foods - their derivation and limitations. In: Radioactivity and the Environment. Proceedings of the 12th Annual Conference of the German-Swiss Health Physics Society.

*Ng, Y.C., C.S. Colsher and S.E. Thompson. 1979. Transfer factors for assessing the dose from radionuclides in agricultural products. In: Biological Implications of Radionuclides Released from Nuclear Industries. Proceedings of an International Symposium on Biological Implications of Radionuclides Released from Nuclear Industries Organized by the International Atomic Energy Agency. Vienna, 26-30 March 1979.

Niemczyk, S.J. 1981. A Model for Radioactive Transport in the Aquatic Ecosystem. Report prepared for the U.S. Nuclear Regulatory Commission NUREG/CR-1597.

Nishita, H., E.M. Romney and K.H. Larson. 1965. Uptake of radioactive fission products by plants. In: Radioactive Fallout, Soils, Plants, Foods, Man. E.B. Fowler (ed.), Elsevier Publishing Company, New York.

Nishita, H., R.M. Haug and A.J. Steen. 1966. Solubility and plant availability of radionuclides in reactor activated soils. Health Physics 12:615-620.

*Nutrition Canada. 1976. Food Consumption Patterns Report. Bureau of Nutritional Sciences, Health Protection Branch Department of National Health and Welfare.

Okamoto. 1980. Effect of the foodchain in radioactivities released from thermal power plants. In: Radiation Protection. A Systematic Approach to Safety. Proceedings of the 5th Congress of the International Radiation Protection Society, Jerusalem, March 1980. Volume 1, pp. 149-152.

Olson, J.S. 1961. Analog computer models for movement of nuclides through ecosystems. In: Radioecology. Proceedings of the First National Symposium on Radioecology held at Colorado State University, Fort Collins, Colorado, September 10-15, 1961. V. Schultz and A.W. Klement, Jr. (eds).

Oniski, Y. 1977. Finite Element Models for Sediment and Contaminant Transport in Surface Waters. Transport of Sediments and Radionuclides in the Clinch River. Report prepared for the Energy Research and Development Administration by Battelle Pacific Northwest Laboratory.

Ophel, I.L. and J.M. Judd. 1967. Experimental studies of radiostrontium accumulation by freshwater fish from food and water. In: Radioecological Concentration Processes. Proceedings of an International Symposium held in Stockholm 25-29 April, 1966. B. Aberg and F.P. Hungate (eds.). Pergamon Press, Toronto.

*Osburn, W.S. 1965. Primordial radionuclides: Their distribution, movement and possible effect within terrestrial ecosystems. Health Physics 11:1275-1295.

*Parfenov, Yu. D. 1974. Polonium-210 in the environment and in the human organism. Atomic Energy Review 12:75-143.

*Paschoa, A.S., G.M. Sigaud, E.C. Montenegro and G.B. Baptista. 1980. Ra-226 collective dosimetry for surface waters in the uranium mining region of Pocos de Caldas. In: Radiation Protection. A Systematic Approach to Safety. Proceedings of the 5th Congress of the International Radiation Protection Society, Jerusalem, March 1980.

Pavlotskaya, F.I., E.B. Tyuryukanova and V.I. Baranov. 1967. On the mobility of strontium and some other components of global fallout in soils and their accumulation in plants. In: Radioecological Concentration Processes. Proceedings of an International Symposium held in Stockholm 25-29 April, 1966. B. Abert and F.P. Hungate (eds.), Pergamon Press, Toronto.

Pelletier, C.A. and P.G. Voilleque. 1971. The behaviour of ^{137}Cs and other fallout radionuclides on a Michigan dairy farm. Health Physics 21:777-792.

*Pentreath, R.J., M.B. Lovett, B.R. Harvey and R.D. Ibbett. 1979. Alpha-emitting nuclides in commercial fish species caught in the vicinity of Windscale, United Kingdom, and their radiological significance to man. In: Biological Implications of Radionuclides Released from Nuclear Industries. Proceedings of an International Symposium on Biological Implications of Radionuclides Released from Nuclear Industries Organized by the International Atomic Energy Agency. Vienna, 26-30 March 1979.

*Persson, R.B.R. 1974. Stable lead and ^{210}Pb in the food chain lichen-reindeer-man. In: Comparative Studies of Food and Environmental Contamination Proceedings Series. FAO/IAEA/WHO Symposium. Otaniemi, Finland. PUblished by International Atomic Energy Agency, Vienna.

Pillai, K.C. and E. Mathew. 1975. Plutonium in the aquatic environment. Its behaviour, distribution and significance. In: Transuranium Nuclides in the Environment. Proceedings of the Symposium on Transuranium Nuclides in the Environment organized by the United States Energy Research and Development Administration and the International Atomic Energy Agency. Held in San Francisco, 17-21 November 1975.

Polikarpov, G.G. 1967. Regularities of uptake and accumulation of radionuclides in aquatic organisms. In: Radioecological Concentration Processes. Proceedings of an International Symposium held in Stockholm 25-29 April 1966. B. Aberg and F.P. Hungate (eds.), Pergamon Press, Toronto.

Polikarpov, G.G., Yu. P. Zaitsev, G.V. Barinov and V.P. Parchevsky. 1967. General features of the concentration processes of radioactive substances by hydrobionts in different seas of the world ocean. In: Radioecological Concentration Processes. Procedings of an International Symposium held in Stockholm 25-29 April, 1966. B. Aberg and F.P. Hungate (eds.), Pergamon Press, Toronto.

Popplewell, D.S., G.J. Ham, T.E. Johnson, J.W. Slather and S.A. Sumner. 1984. The uptake of plutonium-238,239,240, americium-241, strontium-90 and caesium-137 into potatoes. The Science of the Total Environment 38:173-181.

*Poston, T.M. 1982. Observations of the bioaccumulation potential of thorium and uranium in rainbow trout (Salmo gairdneri). Bulletin Environmental Contamination and Toxicology 28:682-690.

Potter, G.D., D.R. McIntyre and D. Pomeroy. 1969. Transport of fallout radionuclides in the grass to milk food chain studies with a germanium lithium detector. Health Physics 16:297-300.

Prister, B.S. (No date). Behaviour of Uranium in the Biological Chain. UNSCEAR Document No. A/AC 82/G/L-1298 AEC-tr. 7128, 194.

Prokhorov, V.M. and L.R. Ginzburg. 1971. Modelling the process of migration and radionuclides in forest ecosystems and description of the model. Ekologiya 5:11-19 (Translation).

Prokhorov, V.M., R.M. Aleksakhin, V.F. Gol'tsev, M.V. Ryzhinskiy and A.M. Margolin. 1973. Mathematical simulation of vertical migration of radionuclides in soils. Soviet Soil Science 5(3):380 (Abstract).

Ragsdale, H.L. and D.J. Shure. 1973. Flood plain transfer and accumulation of ^{137}Cs from a reactor effluent stream. In: Environmental Behaviour of Radionuclides in the Nuclear Industry. Symposium Proceedings. Aix-en-Provence, France, May 14-18, 1973. Published by the International Atomic Energy Agency, Vienna, Austria, 1973.

Rajewsky, B., H. Muth, H.J. Hantke and K. Aurand. 1957. Further results on the question of natural radium content in the human body, food and drinking water. Stahlentherapie 104:157-168.

Rancon, D. 1973. Behaviour in Underground Environments of Uranium and Thorium Discharged by the Nuclear Industry. International Atomic Energy Agency. SM-172/55:333-346.

Rayno, D.R. 1982. Estimated Dose to Man from Uranium Milling Via the Terrestrial Food-Chain Pathway. Report prepared for the U.S. Department of Energy, by the Argonne National Laboratory, Argonne, IL. ANL/ES-125.

Richmond, C.R. 1983. The environmental and biological behaviour of plutonium and some other transuranium elements. Presented at the Annual Meeting of the National Council for Radiological Protection and Measurements, Washington, D.C., April 7, 1983. CONF-830460-4.

*Rumble, M.A. and A.J. Bjugstad. 1986. Uranium and radium concentrations in plants growing on uranium mill tailings in South Dakota. Reclamation and Revegetation Research 4:271-277.

Rundberg, R.S. and B.J. Travis. 1984. Computer modelling of radionuclides transport in Nevada test site TUFF. American Chemical Society 188:42 (Abstract).

Rupp, E.M. 1984. Adult dietary intake and inhalation rates. In: Models and Parameters for Environmental Radiological Assessments. C.W. Miller (ed.). Prepared for the Office of Nuclear Energy, U.S. Department of Energy. Published by the Technical Information Centre, U.S. Department of Commerce.

Russell, R.S. 1960. Radioisotopes and environmental circumstances: the passage of fission products through food chains. In: A Symposium on Radioisotopes in the Biosphere. Sponsored by the University of Minnesota, National Science Foundation, Atomic Energy Commission, and the Agricultural Research Service, U.S. Department of Agriculture. R.S. Caldecott and L.A. Snyder (eds.).

Russell, R.S. 1965. Interception and retention of airborne material on plants. Health Physics 11:1305-1315.

Russell, R.S. 1966. Behaviour of radioactive materials in soil. In: Radioactivity and Human Diet. R.S. Russell (ed.) Pergamon Press, Toronto, Chapter 6, pp. 107-126.

Russell, R.S. 1966. Entry of radioactive materials into plants. In: Radioactivity and Human Diet. R.S. Russell (ed.). Pergamon Press, Toronto. Chapter 5, pp. 89-104.

Russell, R.S. 1967. Uptake and accumulation of radioactive substances in terrestrial plants - The radiobiological aspect. In: Radioecological Concentration Processes. Proceedings of an International Symposium held in Stockholm 25-29 April 1966. B. Aberg and F.P. Hungate (eds.), Pergamon Press, Toronto.

*Russell, R.S. and K.A. Smith. 1966. Naturally occurring radioactive substances: The uranium and thorium series. In: Radioactivity and Human Diet. R.S. Russell (ed.), Pergamon Press, Toronto. Chapter 17, pp. 367-379.

Saas, A. and A. Grauby. 1973. Mécanismes de transfert dans les sols cultivés des radionucléides rejetés par les centrales electro-nucléaires dans le system fleuve-sol irrigué-nappe. In: Environmental Behaviour of Radionuclides Released in the Nuclear Industry. Symposium Proceedings. Aix-en-Province, France, May 14-18, 1973. Published by the International Atomic Energy Agency, Vienna, Austria, 1973.

Sam, D., W.F. Williams, D.D. Rockman and J.T. Allen. 1978. Transfer coefficients of radionuclides in the milk of dairy cows. Naval Surface Weapons Center Report NSWC/WOL TR78-58.

Sam, D., W.F. Williams, D.D. Rockmann and J.T. Allen. 1980. Transfer coefficients of radionuclides secreted in milk of dairy cows. Journal of Dairy Science 63:1447-1450.

Sansom, B.F. 1964. The transfer of plutonium-239 from the diet of a cow to its milk. British Veterinary Journal 120:158-161.

*Sansom, B.F. and R.J. Garner. 1966. The metabolism of radium in dairy cows. Biochemical Journal 99:677-681.

Sato, Y., A. Fujita, P.A. Chambre and T.H. Pigford. 1982. Effect of solubility-limited dissolution on the migration of radionuclid chains. Transactions of the American Nuclear Society 43:64-66.

Schaeffer, R. 1975. The effect of sediment displacement on the dispersal of radionuclides. In: Proceedings of an International Symposium on Radiological Impacts of Releases from Nuclear Facilities into Aquatic Environments. Held at Otaniemi, Finland, 30 June to 4 July 1975. Conf. 750 662 STI/PUB-406, pp. 263-274. (Translated by S.D. Blalock, Jr. for Oak Ridge National Laboratory. ORNL-TR-4348.)

Schell, W.R., A.L. Sanchez, T.H. Sibley and J.R. Clayton, Jr. 1980. Distribution coefficients for radionuclides in aquatic environments III. Adsorption and desorption studies of 106-Ru, 137-Cs, 241-Am, 85-Sr, and 237-Pu in marine and freshwater systems. Report prepared for the Nuclear Regulatory Commission. NUREG/CR 0803.

Schell, W.R., T.H. Sibley, A.E. Nevissi, A.L. Sanchez, J.R. Clayton, Jr. and E.A. Warts. 1981. Distribution Coefficients for Radionuclides in Aquatic Environments. Volume I. Methodology. Report prepared for the U.S. Nuclear Regulatory Commission.

Schulz, R.K., G.A. Tompkins and K.L. Babcock. 1975. Uptake of plutonium and americium by plants from soils. In: Transuranium Nuclides in the Environment. Proceedings of the Symposium on Transuranium Nuclides in the Environment organized by the United States Energy Research and Development Administration and the International Atomic Energy Agency. Held in San Francisco, 17-20 November 1975.

*Schuttelkopf, H. and H. Kiefer. 1980. The radium contamination in the southern Black Forest. In: Radiation Protection. A Systematic Approach to Safety. Proceedings of the 5th Congress of the International Radiation Protection Society, Jerusalem, March 1980.

Schuttelkopf, H. and H. Kiefer. 1982. Radium-226 contamination of the Black Forest and the radioecological behaviour of radium. In: Environmental Migration of Long-Lived Radionuclides. Proceedings of an International Symposium on Migration in the Terrestrial Environment of Long-Lived Radionuclides from the Nuclear Fuel Cycle. Knoxville, Tennessee, USA, 27-31 July 1981. Published by the International Atomic Energy Agency.

Schwarz, G. and F.O. Hoffman. 1980. Imprecision of dose predictions for radionuclides released to the environment; An applicaton of a Monte Carlo simulation technique. Environment International 4:289-297.

Schwarzer, K. 1979. Radionuclide transport in soil - Description and application of a calculation model. Nuclear Technology 46:248-254.

*Scott, R.C. 1961. Radium in natural waters in the United States. In: Radioecology. Proceedings of the First National Symposium on Radioecology held at Colorado State University, Fort Collins, Colorado, September 10-15, 1961. V. Schultz and A.W. Klement, Jr. (eds.).

Sehmel, G.A. 1978. Airborne particulate concentrations and fluxes at an active uranium mill tailings site. Presented at OECD Stabilization and Environmental Impact of Uranium Mill Tailings Conference. Albuquerque, July 1978. pp. 65-84.

Shaeffer, D.L. 1977. AQUAMOD - Computer code for simulating bioaccumulation and transport of radionuclides in aquatic environments. Health Physics 33(6):652. (Abstract).

Sharp, R.D. and C.F. Baes. 1982. Simulation of Radionuclide Transport in U.S. Agriculture. Report prepared by the Oak Ridge National Laboratory.

*Sheppard, M.I. 1980a. The Environmental Behaviour of Radium. Atomic Energy of Canada Limited. AECL-6796. Whiteshell Nuclear Research Establishment, Pinawa, Manitoba.

*Sheppard, M.I. 1980b. The Environmental Behaviour of Uranium and Thorium. Atomic Energy of Canada Limited. AECL-6795. Whiteshell Nuclear Research Establishment.

*Sheppard, M.I. and D.H. Thibault. 1984. Natural uranium concentrations of native plants over a low-grade ore body. Canadian Journal of Botany 62(5):1069-1075.

Sheppard, S.C. 1985. Use of the food-chain Model FOOD III and the Soil Model SCEMR to Assess Irrigation as a Biosphere Pathway. Atomic Energy of Canada Limited AECL-8380.

Shih, C.S. and E.F. Gloyna. 1967. Radioactivity Transport in Water: Mathematical Model for the Transport of Radionuclides. Report to the U.S. Atomic Energy Commission EHE-04-6702, CRWR-18.

Shih, C.S. and E.F. Gloyna. 1980. Mathematical model for the transport of radionuclides in stream system. In: Environmental Surveillance in the Vicinity of Nuclear Facilities. Proceedings of a Symposium sponsored by the Health Physics Society. W.C. Reinig (ed.), Charles C. Thomas, Publisher.

*Shor, R.W. 1984. Aquatic food-chain transport. In: Models and Parameters for Environmental Radiological Assessments. C.W. Miller (ed.). Prepard for the Office of Nuclear Energy, U.S. Department of Energy. Published by the Technical Information Centre, U.S. Department of Commerce.

Shor, R.W. and D.E. Fields. 1980. Agricultural factors affecting the radionuclide foodchain pathway: Green forage consumption of dairy-cows. Health Physics 39(2):325-332.

Shull, R.D. and E.F. Gloyna. 1968. Radioactivity Transport in Water: Simulation of Sustained Releases to Selected River Environments. Report to the U.S. Atomic Energy Commission EHE-04-6801.

Shure, D.J. and M.R. Gottschalk. 1978. Radiocesium transfer through aerial pathways in a South Carolina floodplain forest. In: Environmental Chemistry and Cycling Processes. Proceedings of Symposium held at Augusta, Georgia, April 28 - May 1. D.C. Adriano and I.L. Brisbin, Jr. (eds.).

Silker, W.B., P.G. Heasler and L.E. Santos. 1980. Diffusion and Exhalation of Radon from Uranium Tailings. Report prepared for the Nuclear Regulatory Commission. NUREG/CR-1138.

Simmonds, J.R. and G.S. Linsley. 1981. A dynamic modelling system for the transfer of radioactivity in terrestrial food chains. Nuclear Safety 22(6):766-777.

*Simmonds, J.R., G.S. Linsley and J.A. Jones. 1979. A General Model for the Transfer of Radioactive Materials in Terrestrial Food Chains. National Radiological Protection Board, Harwell, Didcot, Oxon OX110RQ, Report No. NRPB R89.

Skinner, D.J. 1982. Contaminaton of Soil and Foliage as a Fraction of Distance Downwind from Uranium Mill Tailings. Report prepared for the Department of Energy DOE/EV/10305-9.

Smith, M.H., J.J. Alberts, D.C. Adriano, K.W. McLeod and J.E. Pinder, III. 1983. Critical Pathways of Radionuclides to Man from Agro-Ecosystems. Report to the U.S. Nuclear Regulatory Commission by the Savannah River Ecology Laboratory.

Spalding, B.P., T.E. Cerling. 1979. Association of Radionuclides with Streambed Sediments in White Oak Creek Watershed. Oak Ridge National Laboratory Report ORNL/TM-6895.

*Stanley, R.E., A.A. Mullen and E.W. Bretthauer. 1971. Transfer to milk of ingested radiolead. Health Physics 21:211-215.

*Stegnar, P. and I. Kobal. 1982. Uptake and distribution of radium and uranium in the aquatic food chain. In: Environmental Migration of Long-Lived Radionuclides. Proceedings of an International Symposium on Migration in the Terrestrial Environment of Long-Lived Radionuclides from the Nuclear Fuel Cycle. Knoxville, Tennessee, USA, 27-31 July 1981. Published by the International Atomic Energy Agency.

Steinhauer, C. 1984. Comparison of the foodchain transport models of WASH-1400 and MARC Using the Accident Consequence Model UFOMOD. Institut fur Neutronenphysik and Reaktortechnik. Projekt Nukleare Sicherheit KFK 3907.

Steinhauer, C. 1984. Preliminary Investigations of the Significance of the Ingestion Pathway Following Accidental Releases with Actinides. Institu für Neutronenphysik und Reaktortechnik, Projekt Schneller Brûter.

Strandberg, G.W. and S.E. Shumate, II. 1982. Accumulation of Uranium, Cesium and Radium by Microbial Cells. Bench-Scale Studies. Oak Ridge National Laboratory Report ORNL/TM-7599.

*Straub, C.P., G.K. Murthy and J.E. Campbell. 1961. Radionuclides in foods. Journal of the American Dietetic Association 38:15-21.

Sumerling, T.J., N.J. Dodd and N. Green. 1984. The transfer of strontium-90 and caesium-137 to milk in a dairy herd grazing near a major nuclear installation. The Science of the Total Environment 34:57-72.

Sumiya, M., S. Uchida and K. Yanagisawa. 1985. Movement of radio and stable elements in soil-agricultural products-man pathway. Transfer of radionuclides to agricultural products by root uptake. Journal of Radiation Research 26(1):80 (Abstract).

Sumiya, M., Y. Muramatsu, S. Uchida and K. Yanagisawa. 1984. Movement of radio and stable elements in soil-agricultural product-man pathway (4). Removal of radionuclides from agricultural product by cooking. Journal of Radiation Research 25(1):12 (Abstract).

*Swanson, S. 1982. Levels and Effects of Radionuclides in Aquatic Fauna of the Beaverlodge Area (Saskatchewan). Saskatchewan Research Council Publication No. C-806-5-E-82.

*Swanson, S.M. 1985. Food-chain transfer of U-series radionuclides in a northern Saskatchewan aquatic system. Health Physics 49(5):747-770.

*Swanson, S. and Z. Abouguendia. 1981. The Problem of Abandoned Uranium Tailings in Northern Saskatchewan. An Overview. Saskatchewan Research Council Publication No. C-805-40-C-81.

*Swanson, S.M. et al. 1985. A study of the distribution of naturally occurring radionuclides in freshwater benthos and their environment. Phase II Report Field Program. A report prepared for The National Uranium Tailings Program, Canada Centre for Mineral and Energy Technology; Energy, Mines and Resources Canada.

Ter Haar, G. 1970. Air as a source of lead in edible crops. Environmental Science and Technology 4(3):226-229.

Thompson, J.L. 1984. Laboratory and Field Studies Related to the Radionuclide Migration Project (October 1, 1983 - September 30, 1984). Report prepared by Los Alamos National Laboratory.

*Thompson, S.E., C.A. Burton, D.J. Quinn and Y.C. Ng. 1972. Concentration Factors of Chemical Elements in Edible Aquatic Organisms. Rev. 2. Report by the University of California, Lawrence Livermore Laboratory. UCRL-50564 (Rev. 1).

Thornton, I. and P. Abrahams. 1983. Soil Ingestion - A major pathway of heavy metals into livestock grazing contaminated land. The Science of the Total Environment 28:287-294.

Tikhomirov, F.A., R.M. Alexakhin and E.A. Redorov. 1972. Migration of radionuclides in forests and the effect of ionizing radiations on tree plantations. In: Peaceful Uses of Atomic Energy. Proceedings of the Fourth International Conference, Geneva 6-16 September 1971, Volume II. Published by the International Nations and the International Atomic Energy Agency (Article in Russian, Abstract in English).

Timofeeva, N.A. and N.V. Kulikov. 1967. The role of freshwater plants in accumulation of ^{90}Sr and its distribution over the components of a reservoir. In: Radioecological Concentration Processes. Proceedings of an International Symposium held in Stockholm 25-29 April 1966. B. Aberg and F.P. Hungate (eds.), Pergamon Press, Toronto.

Toste, A.P., L.J. Kirby, W.H. Rickard and D.W. Robertson. 1984. Radionuclide characterization, migration and monitoring at a commercial low-level waste disposal site. In: Radioactive Waste Management. Proceedings of an International Conference on Radioactive Waste Management held by the International Atomic Energy Agency, Seattle, 16-20 May 1983. Published by the International Atomic Energy Agency, 1984.

Townsley, S.J. 1967. The concentration of ^{90}Sr and other nuclides in fish. In: Radioecological Concentration Processes. Proceedings of an International Symposium held in Stockholm 25-29 April, 1966. B. Aberg and F.P. Hungate (eds.) Pergamon Press, Toronto.

Trabalka, J.R. and C.T. Garten. 1983. Behaviour of the long-lived synthetic elements and their natural analogs in food chains. Advances in Radiation Biologgy 10:39-104.

Tschurlovits, M. and G. Prohaska. 1984. Problems in establishing models for prediction of environmental migration of radionuclides in the aquatic pathway. In: Regional Congress of IRPA, Austria-Hungary-Yugoslavian Radiation Protection Meeting: Recent Developments and New Trends in Radiation Protection: Proceedings Volume 2.

Uchida, S., K. Yanagisawa and M. Sumiya. 1985. Movement of radio and stable elements in soil-agricultural product-man pathway (5). Transfer of radionuclide to agricultural products by root uptake (III). Journal of Radiation Research 26(1):80 (Abstract).

Ueda, T., R. Nakamura and Y. Suzuki. 1985. Position of sediments in transfer of radionuclides released into coastal sea to human beings. Bulletin of the Japanese Society of Scientific Fisheries 51(8):1319-1324.

USEPA. 1983. Potential Health and Environmental Hazards of Uranium Mine Wastes Volume 3. EPA-520/1-6-83-007-VOL-3.

USEPA. 1983. Potential Health and Environmental Hazards of Uranium Mine Wastes Volume 2. EPA-520/1-6-83-007-VOL-2.

USEPA. 1984. Radionuclides: Background Information Document for Final Rules. Volume 1. EPA/520/1-84/022/1 Volume 1.

Uzzan, G. 1978. Transfert des radionucléides dans l'environement et modalités d'atteinte de l'homme. Agriculture (Paris) 416:52-54.

Van den Hoek, J., R.J. Kirchmann, J. Colard and J.E. Sprietsma. 1969. Importance of some methods of pasture feeding, of pasture type, and of seasonal factors on ^{85}Sr and ^{134}Cs transfer from grass to milk. Health Physics 17:691-700.

Van der Borght, O., R. Kirchmann, S. van Puymbroeck and E. Fagniart. 1967. ^{45}Ca, ^{85}Sr and ^{134}Cs absorption and translocation in isolated root systems of tomato plants. In: Radioecological Concentration Processes. Proceedings of an International Symposium held in Stockholm 25-29 April, 1966. B. Aberg and F.P. Hungate (eds.) Pergamon Press, Toronto.

*van Dorp, F., R. Eleveld and M.J. Frissel. 1979. A new approach for soil-plant transfer calculations. In: Biological Implications of Radionuclides Released from Nuclear Industries. Proceedings of an International Symposium on Biological Implicatons of Radionuclides Released from Nuclear Industries Organized by the International Atomic Energy Agency. Vienna, 26-30 March 1979.

Vanderploeg, H.A., D.C. Perzych, W.H. Wilcox, J.R. Kercher, S.V. Kaye. 1975. Bioaccumulation Factors for Radionuclides in Freshwater Biota. U.S. Energy Research and Development Administration Report ORNL-5002 Oak Ridge National Laboratory.

*Verkhovskaja, I.N., P.P. Vavilov and V.I. Maslov. 1967. The migration of natural radioactive elements under natural conditions and their distribution according to biotic and abiotic environmental components. In: Radioecological Concentration Processes. Proceedings of an International Symposium held in Stockholm 25-29 April, 1966. B. Abert and F.P. Hungate (eds.), Pergamon Press, Toronto.

*Verkhovskaya, I.N., P.P. Vavilov and V.I. Maslov. 1972. Distribution and redistribution of uranium, radium and thorium in natural biogeocenoses. (Translated from Radioekologicheskie issledovaniya v prirodnykh biogeotsenozakh, Izdatel'stuo Nauk, Moscow.)

Voshell, J.R., Jr., J.S. Eldridge and T.W. Oakes. 1982. Radionuclide transfer by aquatic insects in a contaminated pond. Health Physics 43(1):159-160 (Abstract).

*Watters, R.L. and J.F. McInroy. 1969. The transfer of ^{210}Po from cattle feed to milk. Health Physics 16:221-225.

*Watters, R.L. and W.R. Hansen. 1970. The hazards implications of the transfer of unsupported ^{210}Po from alkaline soil to plants. Health Physics 18:409-413.

Ward, G.M., J.E. Johnson and L.B. Sasser. 1967. Transfer coefficients of fallout cesium-137 to milk of dairy cattle fed pasture, green-cut alfalfa or stored feed. Journal of Dairy Science 50:1092-1096.

*Watabe, T., S. Uchida and H. Kamada. 1984. Transfer of radionuclides through soil-plant pathway. Journal of Radiation Research 25:274-282.

Watson, A.P., E.L. Etnier and L.M. McDowell-Boyer. 1983. Radium-226 in Drinking Water and Terrestrial Food Chains: A Review of Parameters and an Estimate of Potential Exposure and Dose. Report prepared for the Florida Institute of Phosphate Research by Oak Ridge National Laboratory ORNL/TM-8597.

*Welford, G.A. and R. Baird. 1967. Uranium levels in human diet and biological materials. Health Physics 13:1321-1324.

Whicker, F.W. 1978. Bilogical interactions and reclamation of uranium mill tailings. In: Symposium on Uranium Mill Tailings Management. Ft. Collins, CO. Nov 20-21, 1978. Colorado State University.

*Whicker, F.W. and V. Schultz. 1982a. Quantitative aspects of radionuclide transport. In: Radioecology: Nuclear Energy and the Environment Chapter 1, Volume II. CRC Press, Inc., Boca Raton, Florida.

*Whicker, F.W. and V. Schultz. 1982b. Radionuclide behaviour in ecosystems. In: Radioecology: Nuclear Energy and the Environment, Chapter 5, Volume I. CRC Press Inc., Boca Raton, Florida.

Whicker, F.W., G.C. Farris, and A.H. Dahl. 1967. Concentration patterns of ^{90}Sr, ^{137}Cs and ^{131}I in a wild deer population and environment. In: Radioecological Concentration Processes. Proceedings of an International Symposium held in Stockholm 25-29 April, 1966. B. Aberg and F.P. Hungate (eds.) Pergamon Press, Toronto.

White, A. and E.F. Gloyna. 1969. Radioactivity Transport in Water: Mathematical Simulation. Report to the U.S. Atomic Energy Commission. Technical Report No. 19.

Wildung, R.E. T.R. Garland and D.A. Catalde. 1979. Environmental processes leading to the presence of organically bound plutonium in plant tissues consumed by animals. In: Biological Implications of Radionuclides Released from Nuclear Industries. Proceedings of an International Symposium on Biological Implications of Radionuclides Released from Nuclear Industries Organized by the International Atomic Energy Agency. Vienna, 26-30 March 1979.

*Williams, A.R. 1982. Biological uptake and transfer of radium-226: A review. In: Environmental Migration of Long-Lived Radionuclides. Proceedings of an International Symposium on Migration in the Terrestrial Environment of Long-Lived Radionuclides from the Nuclear Fuel Cycle. Knoxville, Tennessee, U.S.A., 27-31, July 1981. Published by the International Atomic Energy Agency.

Wlodek, S. 1967. The behaviour of ^{137}Cs in freshwater reservoirs, with particular reference to the reactions of plant communities to contamination. In: Radioecological Concentration Processes. Proceedings of an International Symposium held in Stockholm 25-29 April, 1966. B. Aberg and F.P. Hungate (eds.) Pergamon Press, Toronto.

Wogman, N.A., W.B. Silker, J.A. Glissmeyer and G.W.R. Endres. 1980. Methods for Assessing Background Levels of Radiation and Radioactive Materials in the Environment Around Uranium Mills. Report prepared for the U.S. Nuclear Regulatory Commission NUREG/CR-1253.

Yanagisawa, K. and S. Uchida. 1985. Movement of radio and stable elements in soil-agricultural product-man pathway (7). Uptake-transport of radionuclides from leaves-1. Journal of Radiation Research 26(1):80 (Abstract).

Yanagisawa, K., M. Sumiya and S. Uchida. 1984. Movement of radio and stable elements in soil-agricultural product-man pathway (3). Uptake-Transport of radionuclides in vegetables .1. Journal of Radiation Research 25(11):12 (Abstract).

*Yuan, Y.C. and C.J. Roberts. 1982. Comparative assessment of radiological impact from uranium and thorium milling. In: Management of Wastes from Uranium Mining and Milling. Proceedings of an International Symposium on Management of Wastes From Uranium Mining and Milling. Albuquerque, New Mexico, 10-14 May 1982. Published by the International Atomic Energy Agency, Vienna.

*Zach, R. 1978. Food II: An Interactive Code for Calculating Concentrations of Radionuclides in Food Products. Atomic Energy of Canada Limited. AECL-6305.

*Zach, R. 1980a. NEPTUN: An Interactive Code for Calculating Doses to Man due to Radionuclides in Aquatic Food Chains. Atomic Energy of Canada Limited AECL-6450.

*Zach, R. 1980b. Transfer Coefficients to Terrestrial Food Products in Equilibrium Assessment Models for Nuclear Installations. Atomic Energy of Canada Limited. AECL-6449.

Zuter, M., J.M. Ridgeway and D.R. Miller. 1979. A study of atmospheric radionuclide transport and exposure using trajectory analysis. In: Biological Implications of Radionuclides Released from Nuclear Industries. Proceedings of an International Symposium on Biological Implications of Radionuclides Released from Nuclear Industries Organized by the International Atomic Energy Agency. Vienna, 26-30 March 1979.